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KANSAS UNIVERSITY SCIENCE BULLETIN.

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ON HEREDITY IN CERTAIN MICRO-ORGANISMS.

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With plates I to IV.

THE aim of the work described in this paper has been to conduct with certain micro-organisms investigations on heredity similar to those long practiced with higher plants and animals. From the offspring of single varying cells new races of yeast and bacteria have been obtained, which differ morphologically and physiologically from the type, and this paper is mainly given to a study of the origin and characteristics of these new races.

In order to accomplish this work, involving as it does the selection and isolation of single varying cells lying among thousands of normal ones, a new method of isolation had to be devised, a method which is described in another part of this paper.

The investigations described below have had to do principally with the yeast *Saccharomyces anomalus* and the bacterium *Bacillus coli communis;* though some work was also done with *B. typhosus* and a large, spore-forming bacillus, probably *B. megatherium.* In every case the work was done with absolutely pure cultures, known to be such because known to be the descendants of single isolated normal cells.

In reviewing the literature on this subject, I shall confine myself largely to those relatively few papers which deal with the heredity of new races which have apparently arisen spontaneously from cells varying independently of the environments, and I shall omit the large number of publications

having to do with modifications of micro-organisms induced by altered conditions of culture, unless such modifications are known or supposed to originate from single varying cells.

Hansen, who has been the pioneer in work of this character conducted on yeasts, succeeded in obtaining asporogenous races of *Sacchoromyces pastorianus* I, II, and III, *S. cerevisiæ* I, *S. ellipsoideus* I and other normally spore-bearing species by plating in gelatin and testing the offspring of various colonies by placing them on gypsum blocks. He found great variation in the spore-producing power of these colonies, varying from normal to races which have remained asporogenous, though cultivated under diverse conditions for twelve years. He found that some varieties, as *johannesberg* II, could not be made to produce asporogenous forms, except by previously cultivating the yeast at temperatures approaching the optimum temperature of budding, and that in practically all forms the per cent. of asporogenous varieties was increased by this preliminary treatment. Here we have to do with a possible transformation associated with selection; but in the case of those forms which gave asporogenous varieties without this treatment, for example *S. pastorianus* I, which gave five to ten per cent. of asporogenous colonies at the start, we deal with probably spontaneous variations.

Associated with the loss of power of producing spores, Hansen found the loss of power to produce veils. *S. anomalus*, however, did not lose this faculty in asporogenous varieties.

Further, the author found types presenting growth of cheesy character and branching filaments, forms which persisted for a number of generations. Again, cells showing a tendency to extend in an elongated mycelium-like form were found to transmit their peculiarities. In the case of *S. ludwigii* the mycelium-like type returned to the normal form when grown in wort. In type No. I of *carlsberg*, Hansen obtained a strain presènting abnormally elongated cells which preserved its peculiarities during two months' cultivation in wort. This type finally returned to its normal form.

A number of races physiologically different which proceed from the same pure culture are mentioned by Hansen. Among these are types showing an increased power of pro-

ducing alcoholic fermentation. A type of *S. cerevisiæ* produced one to three volumes per cent. more alcohol than the parent form from which it was derived.

Other strains differed from their types in their power of forming invertase and maltase. A race of *S. pastorianus* I for some time failed to impart to beer a bitter taste and disagreeable odor characteristic of the type; and variations of other types having to do with the clarification of beer and other aspects of brewing are mentioned by the author.

These physiological types originated for the most part in changed conditions of cultivation. For instance, Biernacki and, later, Märcker, Haydruck and Effront have found that the addition of small quantities of antiseptics to cultures of certain yeasts may increase their fermentative power. But Hansen is of the opinion that in some of these cases, at least, we have to do with a selection of cells endowed with certain physiological characteristics and not with mere transformation. The relative weight of these two factors in such experiments is a matter hard to determine.

M. W. Beijerinck (1897) isolated from a species of *Schizosaccharomyces* found on fruits of tropical origin two sorts of colonies on wort gelatin. One sort, brown in color, was asporogenous; the other, which was white, produced spores, and intermediate forms occurred. On testing the offspring of these colonies, the white variety was found to give nearly all white colonies; the brown gave brown; while the intermediate types gave both white and brown. Certain morphological and physiological differences were also characteristic of the different races. The brown, for instance, divide without forming the characteristic "yokes." The asporogenous race showed a loss of power of producing trypsin. There was little difference in fermentative power, but the chief fermentation was most marked in the spore-bearing form; the secondary, in the asporogenous type.

In *Schizosaccharomyces pombe* this author found white and brown colonies, one of which was more productive of spores than the other. In *S. asporus* he found white colonies with thick, short cells, and brown colonies with similar cells, but having in addition long, thin ones. He found this same

tendency to split into sporogenous and asporogenous races in other species of budding organisms.

Alfred Jörgensen (1898) has described new races, differing in their qualities with respect to brewing, which may come from the offspring of a single cell. This author has successfully selected races having better clearing powers and others with superior aromatic qualities.

H. Will (1899) noted a variation in the types of colonies produced on gelatin by four bottom beer yeasts experimented on. These types varied in the degree of regularity of the colony nucleus and outline. Long growing on one medium tended to fix the type so that fewer variations of this sort were observed. The author found that irregular forms more often occurred on cultures taken from the pellicle, and he noted a parallelism between the tendency to early formation of pellicles and the early formation of outgrowths in colonies. The pellicle of some forms produced irregular colonies, while the sediment of the same type produced regular, though sometimes irregular also. Repeated transfers in wort and beer gelatin tended to restore regularity to the forms of colonies. The outgrowths of irregular colonies were sometimes composed of elongated cells and sometimes of spherical. Spore formation diminished in forms producing irregular colonies and returned again as the colonies became more regular. Races exhibiting cells of mycelium-like form retained their characteristics during three years of repeated transfers in a favorable medium, and the author regards such types as a sort of generation in the cycle of their life-history. He believes that successive phases or generations occur in these plants, and that the reported formation of new races may be only the inception of new generations.

M. Hartman (1903) found in colonies of *Torula colliculosa* on wort gelatin and agar peculiar colonies having elevations composed of cells larger than the normal. Cultures containing these cells have the power of fermenting maltose, a property not possessed by cultures which lack the large cells. Other sugars tested—raffinose, cane, grape and fruit sugars—were fermented by both type and variation alike.

W. Henneberg (1903) found giant cells in each of two types of distillery yeasts, the large size of which was transmitted to daughter-cells budding from them. The tendency to store glycogen was also found to be hereditary in these types.

W. W. Lepeschkin (1903) found in *Schizosaccharomyces pombe* and *S. melacei* cells which grew out in the form of mycelia, instead of dividing in the usual manner of the genus. Some of these cells were isolated and found to reproduce the new characteristic. When grown under conditions favoring endogenous spore formation, these cells produced an oidium-like growth, and spore formation was rarely observed. When spores were produced and made to germinate, they reproduced the elongated type of growth peculiar to the new race. The author thinks the new form an example of mutation or heterogenesis.

Comparatively little has been done in selection experiments on bacteria where the isolation of single cells is involved.

H. W. Conn (1899) describes a culture of bacteria, isolated by him from milk, which shows great variability, not due, apparently, to the immediate environment. The color of colonies varied from a milk white to deep orange, and from colonies rapidly liquefying the medium to non-liquefying colonies. By selection of colonies in plate cultures made from a pure culture he obtained pure white and pure orange, as well as liquefying and non-liquefying strains.

A. Meyer (1901) found that the proportion of branched cells in *Bacillus cohærans* is greater in that part of gelatin plates where branched cells were sown; and he concludes that there is a tendency for this peculiarity to be transmitted. He is of the opinion that bacteria are descended from fungi with branched mycelia, and that occasional branching is to be regarded as atavism, not as the formation of a new character.

W. W. Lepeschkin (1904) found in *Bacillus berestnewii* certain branched individuals and also small non-septate mycelia. The offspring of isolated branched cells exhibited five to fifteen per cent. of branched cells after only twenty to fifty offspring had been formed, while the offspring of the unbranched showed none until after many generations of cells

had formed. A culture coming from an isolated mycelium soon reverted to the ordinary branched and unbranched forms, though the mycelium type persisted long enough to show a tendency to heredity. The appearance of these mycelia, apparently, does not depend on temperature or the nature of the substratum. Higher temperatures seem to favor the appearance of branched forms. The author holds that these variations represent new characteristics and are not to be referred to atavism.

R. Massim (1906), working with a pure culture of *Bacillus coli mutabilis*, found that colonies remained white on Endo agar, indicating lack of power to ferment lactose. Transplantations of young colonies continually gave white colonies on this medium, but transfers from older colonies sometimes gave a proportion of distinctly red colonies, which remained red on further transplantation. These red colonies he supposes to arise by mutation in the sense of de Vries.

I.—EXPERIMENTS ON YEAST.

In my own work on *Saccharomyces anomalus*, I have made use of a culture kindly furnished me by Professor Freeman, of the University of Minnesota, a culture which originally came from Doctor Barker, of England. My researches were conducted in two directions: First, the selection of cells varying from the normal in size; second, the selection of cells varying in form.

In the first series I attempted to obtain a race exhibiting cells permanently larger than the normal by repeated selection of cells of unusual size. As in all experiments made in the course of this work, the series was begun with a pure culture proceeding from a single isolated normal cell. Cultures were made for the most part in glucose bouillon in hanging drops, and the isolated cells were grown in the same medium. In conducting these experiments, a cell, considerably larger than the normal, was isolated, and, after a considerable number, often hundreds, of offspring had been formed, a second large cell was isolated from these, and so on. A check consisting of unselected cells was frequently compared under similar conditions.

In one series this repeated selection was practiced twelve

times; in another, ten times. In both series the results were negative so far as obtaining a permanently modified race is concerned. It was evident in a number of cases that the first few generations proceeding from a large cell consisted of abnormally large cells, but after repeated budding the cell type resumed its normal size. The character of the selected type was noted in hanging drop cultures during the progress of the experiments, and in tube cultures months after the completion of the selection.

In these experiments precautions were taken to avoid reselecting the same large cell in the subsequent selection. A number of single large cells were deprived of their buds and isolated in separate droplets, where they were observed to continue to grow and to reach a size far exceeding the normal and to produce a new crop of buds. On being isolated again. and a second time deprived of their buds, these cells usually refused to form new offspring, and showed an irregularity of outline indicating loss of turgidity and death.

In the above series many cell generations intervened between selections, so that a new series was carried out with another yeast to determine the actual number of generations during which a variation in size persists—a difficult thing to do in an ordinary hanging drop. These experiments were conducted in two ways: First, by means of a very fine glass rod or pipette, but little bent at the tip, a daughter cell was separated from the mother at a time when the attachment showed the relationship clearly. This daughter-cell was isolated, and, when it had grown, its first bud was separated, and so on.

A series several generations long was successfully carried out, but the conditions of the experiment were such that it was difficult to get definite results regarding heredity. Either observations had to be kept up night and day, or growth had to be checked during the intervals in the experiment. This last was accomplished by keeping the hanging drop at refrigerator temperature over night. However, this exposure to lower temperatures, together with the possible injury to cells in the process of separation, subjected them to abnormal conditions; and no very satisfactory results were obtained.

In a second attempt, a single cell was drawn into a capillary tube so fine that budding in two directions only was possible, with the result that a single chain of cells was formed in the tube. It was found, however, that the budding of older cells interpolated new cells in the chain, and it was therefore impossible to keep track of successive generations without keeping the tube under observation night and day. So this attempt was, for the time, also abandoned.

The above experiments indicate that repeated selection is necessary in this yeast if an abnormal standard of size is to be kept up; in this matter the yeast resembles higher plants, where quantitive variations do not often persist unless kept up by continuous selection. It is true that we may conceive of a mutation in the direction of size among lower plants as well as in the higher, but the variations observed in the above experiments did not seem to have that character.

In the second series of experiments, conducted on variations in the form of cells, selections of abnormal cells were continued for some weeks before any variations of a permanent character were obtained. In November, 1903, a cell which showed a narrow, mycelium-like outgrowth, was isolated from a hanging drop of glucose broth culture, the cells of which were the offspring of a single normal cell, isolated the previous day. Growth after isolation was slow, but after one or two days the extension and branching of hypha-like outgrowths produced a mass resembling a small mycelium. This showed little yeast character until after two or three days, when it produced at the tips of branches chains of yeast-cells, which began to reproduce by budding after the manner of yeasts. But the majority of these yeast cells were of a character quite different from the typical form of *Saccharomyces anomalus*. There was a tendency to assume elongated forms, to put out hypha-like prolongations which sometimes branch, and to adhere in groups, characteristics not found in the normal type when grown under like conditions. (See photomicrographs. In plate I, figure 1 represents an old wort culture of the parent stock, figure 2 a new race grown under the same conditions, and figure 3 a ten

days' beef-broth culture of the same new race. In plate II, figures 1 and 2 represent respectively the parent stock and a new race derived from it, both glucose agar cultures, about ten days old, and grown under the same conditions. The new race represented in plate II was originated about November 1, 1903, two years and four months before the time of photographing.)

This new race has persisted three years and five months, and constantly exhibits its new characteristic on a great variety of media, and under very diverse conditions of temperature and amount of oxygen. Some of the media tested were beef-peptone broth, ordinary, and modified by the addition of various sugars, in amounts varying from one-half to ten per cent., plain agar, and agar in combination with glucose or glycerin, wort, wort gelatin, acid and alkaline, glucose gelatin, Loeffler's blood serum, prune juice, and Hansen's fluid medium for yeasts. Both acid and alkaline liquid media were used.

The new characteristics persisted at all temperatures employed, varying from low room temperature to 37½ degrees C., and they were found in cultures of all ages, though they were less marked in cultures a few hours old. The tendency to produce very elongated forms is more marked on gelatin than in liquid cultures, and more pronounced in acid broth than in alkaline.

The tendency of the new race to form elongated cells is well shown on gelatin or agar plate cultures, where the parent type cultivated under these conditions shows for the most part colonies with smooth outlines, while new race colonies show ragged outlines, the irregularities being due to outgrowing, filament-like chains of cells. (See photomicrographs, plate IV. Figure 1, colonies of the parent type grown in glucose gelatin; figure 2, colonies of a new race of the same age and grown under similar conditions.) A new race showed this peculiarity over two years after its origin in as marked a degree as at first.

Colonies of both race and check were obtained in a receptacle from which oxygen had been exhausted by the combustion of phosphorus. These colonies were restored to air,

and after a few days an examination of the new race showed the characteristic elongated form.

The peculiarities of the new race are such that they can be better understood by reference to the illustrations than by statistics. However, in order to get some exact data regarding the elongated character of the cells, I obtained the ratio between the length and breadth of 272 cells of the new race and 212 of the check. In all but 70, measurements were taken of the living cells, in order to avoid error due to shrinking in fixation and staining. Measurements were in nearly all cases made with a $\frac{1}{12}$ oil-immersion objective or with a Zeiss F, and with the micrometer scale in a one-inch ocular. Cells from ten different cultures were taken, with one exception all from glucose broth cultures in hanging drops or from test-tubes. In each of the ten cases, with one exception, the check was of the same age as the new race and grown under the same conditions. Much elongated, filament-like cells were not included in the estimate, and for the most part cells were chosen in which the size or the presence of a well-developed bud showed maturity. Ratios were calculated for each cell separately and the average taken of these ratios. The average ratio of length to breadth was in the check (212 cells) 1.190 to 1.000; in the new race (272 cells), 1.441 to 1.000.

New races of the type described above are characterized by a partial loss of the power to produce spores. Many attempts were made to secure abundant spore formation, among them cultivation on potato, on agar of various sorts, and in shallow hanging drops of various liquid media. Actively growing cultures were also placed on gypsum blocks, moist filter-paper, and on a moist sponge. A considerable range of temperature was employed.

Spores were obtained abundantly in shallow hanging drops in one or two cases, and on glucose agar; but in most of the experiments spores were obtained in relatively small numbers. In all successful spore cultures, with the possible exception of one on glucose agar, there were fewer spores formed in the new races than in the check; and in some instances, where considerable numbers were formed in the check, there

were none at all in the new race cultivated under similar conditions.

Many spores of both race and check were separated from the vegetative cells and isolated in fresh nutrient fluid. In some cases the mother-cell containing ripe spores was isolated, while in others spores were removed from the mother-cells and isolated in separate droplets. The earlier stages of the germination of the spores were usually observed, so as to make sure that the new growth was of spore origin. During a period of nearly two years about fifty such isolations of spores or spore groups were made, of which about one-third were taken from cultures of the new races. Since, in a considerable number of cases, mother-cells with four spores or larger spore groups were included in one isolation, the total number of spores under observation was perhaps 200. A very small proportion of these spores developed further than the formation of a few buds or of a small colony. In some cases a colony of several hundred cells would be formed, but no further development could be obtained. From spores or spore groups isolated from the check not above five permanent cultures were obtained, and from the new races none. It is probable that the culture used had, through long cultivation, partially lost its power of producing healthy spores.

Cultures obtained from spores of the check, whether feeble or permanent, showed a great irregularity in the form and size of cells. These cells closely resemble those from the new races originating in varying vegetative cells, exhibiting much the same elongated form and tendency to group. Besides microscopical differences, these new spore races show macroscopical abnormalities in liquid media. Growth is less vigorous, scanty or no pellicles are formed, and there is a greater tendency for the growth to collect in the bottom of the test-tube, leaving a clear liquid above. A culture originating from spores of the check showed both macroscopical and microscopical abnormalities unimpaired after over two years cultivation on various media.

As stated above, no permanent culture was obtained from spores of the new race, though in one case a colony of about 500 cells was obtained, and in another one of 100 or more.

In both of these the irregular character of the new race was reproduced in the offspring, though the irregularity was scarcely greater than that seen in the offspring of check spores.

A similar tendency towards elongation in cultures from old spores was observed by Hansen in *Saccharoymces ludwigii.*

As regards the formation of pellicles, there seems to be no constant difference between the new races and the check. Pellicles are quickly formed in both, and the cells composing them show the morphological differences characteristic of the two types.

The stability of the new races has been tested not only by three years' cultivation in various media, but also by two series of selection experiments.

In one series an attempt was made to determine whether a new race could be made more filamentous by the selection of the more elongated elements. A single, much elongated cell, usually at least five times as long as broad, or a group of united cells including one or more of such filaments, was isolated, and from its offspring a similar selection made. Eleven such selections were successively made, for the most part in hanging drops of glucose bouillon. It was found that during the experiment there was a greater tendency to a more mycelium-like form of cells, but unless kept up by continuous selection, the filamentous type reverted to the original form of the new race. So there was no evidence that the type could be permanently changed in this direction.

In another series selection was made in an opposite direction. Among the elongated cells of the new races there is almost always found a proportion of spherical cells, not grouping or otherwise visibly differing from the parent type. From a new race, taken about twelve days after its origin, and exhibiting well-marked race peculiarities, selection was made of a single spherical cell, or of a spherical cell with its attached bud, and from the offspring of this cell a similar selection was made. A check of unselected race cells was carried on under parallel conditions. While there was some variation in the degree of sphericity of cells, the check showed the same changes; and at the end of a series of ten

successive selections, the series selected showed the same elongated form as the non-selected check. In other words, the continual selection of cells approaching the parent type brought the new race no nearer to that type.

A long series of experiments was conducted to ascertain the nature of the sports giving rise to permanent new races, their relative proportion to normal cells, and the conditions under which they arise.

The type of cell which most frequently produced permanent new races is characterized by one or more long, narrow prolongations attached to the mother-cell. In hanging drop cultures such cells seemed to appear most frequently in beef peptone broth to which one per cent. of glucose had been added. They appeared in both acid and alkaline broth, though in one long series, at least, they seemed most abundant in the alkaline. They were more often found in shallow hanging drops than in deeper ones, and in obtaining them I had best success by sowing fresh cells in long shallow drops, many of which may be made on one cover-glass. Their more frequent appearance in shallow drops may be in part only apparent, since such drops may be more readily searched. They were found on solid as well as liquid cultures.

In a considerable number of experiments the proportion of these cells relative to normal ones was estimated. Taking two of these experiments for illustration, in acid beef peptone broth containing one per cent. glucose they were found after four days' growth at room temperature in proportions varying from 1 in 5000 in some hanging drops to 1 in 46,000 in others. In roll tubes of glucose gelatin, after six days at room temperature, the proportion varied from 1 in 1000 to 1 in 10,000. On the average, they appeared in numbers less than the proportion 1 in 5000. Sometimes long series of hanging drop cultures, including hundreds of thousands of cells, gave no variations of this character. In the above estimates I refer to comparatively young cultures. On old cultures on solid media the proportion of irregular cells may be somewhat larger.

Most of these variations were found at room temperature. They were found in young as well as old cultures, and in two

instances were found among the offspring of single normal cells isolated on the previous day.

A large number of these cells failed to grow when isolated, and checks consisting of single normal cells isolated and brought to a successful growth under parallel conditions are evidence that the failure to grow is referable to the nature of the abnormal cells and not to the condition of growth. During a period of about two and a half years no less than fifty cells of the typical sport type, or otherwise abnormally elongated, were isolated. From these isolations less than ten new races of permanent character were obtained.

The early development of the new races is slow, and, as stated above, they often exhibit during the first few days a connected mass resembling a mycelium of the higher fungi. But after budding has once freely begun the new races are as vigorous as the type.

About two years after its origin, a new race of *Saccharomyces anomalus* was tested as to its powers of competition with the parent type when mixed with it in cultures. A single cell was isolated from the parent type, and one from the new race, and, after growth had well begun in hanging drops, an approximately equal number of offspring of each cell were mixed and transfers made from the mixture to one per cent. glucose broth in test-tubes, to one per cent. glucose agar, and to hanging drops of glucose broth. After two days' growth transfers were made from each of the three cultures to fresh media of the same kind. These transfers were repeated every two or three days through eight subcultures, the experiment lasting twenty-three days. At the end of this time it was found that the new race had persisted in the hanging drop cultures, had apparently outgrown the parent type in both pellicle and sediment of the broth test-tube cultures, but had so far diminished in the agar cultures that at the margin of the growth it had nearly disappeared and was but little more evident at the center. The hanging drop culture was kept at room temperature; the test-tube cultures at about thirty degrees C.

The agar series was further continued to the fifteenth subculture, and during the last seven transfers it was kept at

room temperature and transfers were made at longer intervals. At the end of this series, extending in all over sixty-five days, cells having the character of the new race reappeared in larger numbers at about the eleventh transfer and continued to increase to the end. As a further test of the persistence of the new race in the agar series, a transfer was made from transfer No. 10 to glucose broth. The new race appeared at once in a considerable proportion of cells, and continued to increase proportionately to the end of a broth series of six transfers. As controls, the parent type and the new race, unmixed, were cultivated on agar and continued through seven transfers at the same intervals and under the same conditions as the series just described. At the end both were found to have retained their characteristics unchanged.

The original mixed broth culture was continued under the same conditions as the agar series to the sixteenth subculture, when the proportion of elongated cells was found to be as large as in an unmixed new race culture kept as a control under parallel conditions. From transfer No. 11 of this mixed broth culture a transfer was made to agar and continued through six agar transfers under the same conditions as the other agar series. The new race characteristics were retained on the solid medium.

In order to confirm the results above given, a second series was begun, starting with mixed new race and parent cells, each proceeding from single cells of the two types, as in the first series. Cultures were continued on both glucose broth and on glucose agar kept at room temperature and transferred six times, at intervals of about five days. In both media the new race persisted as in the first series.

For further confirmation a third series was carried out, this time not beginning with single cells but with a broth culture to which five loopfuls of each type had been added. Transfers were made to glucose broth, plain broth, and glucose gelatin. These were grown at room temperature for twenty-three days and transferred three times. Controls of unmixed cultures of each type were carried through parallel

conditions, a pair for each of the three media. The new race persisted in all media, being least prominent in the gelatin.

Summarizing all experiments with mixed cultures, there is evidence that the new race not only persists in all cultures through as many as sixteen transfers, extending over a period of sixty-five days, but in broth cultures seems to outgrow the parent type. In agar cultures grown at thirty degrees C., with frequent transfers, the new race diminished, but reasserted itself at once on being transferred to broth, and more gradually by continued transfers on agar at room temperature at longer intervals.

Only one strain of *Saccharomyces anomalus*, that consisting of the offspring of a single cell isolated from the culture mentioned at the beginning of this paper, has been employed during the three-year period covered by these experiments; and during this period the type has varied little as regards its capacity of producing sports. There is no evidence of "mutations periods" arising independently of cultural conditions.

Experiments have been begun to ascertain whether variations similar to those found in *Saccharomyces anomalus* occur in other yeasts also. A pink yeast isolated from cider was kept under observation for about a month, and many thousands of cells proceeding from a single isolated cell and grown in shallow hanging drops were searched for variations similar to those which originated new races in *S. anomalus*. Few abnormal cells were found, and these, when isolated, reverted to the parent type. Similar negative results have been obtained from a white yeast isolated from cider and from a large-celled white yeast from dough.

PHYSIOLOGICAL CHARACTERISTICS OF NEW RACES.

New races of the morphological character described above were tested as to their power of fermenting sugars, their power of liquefying wort gelatin, and their resistance to heat and drying.

Since the ordinary fermentation tubes do not give reliable quantitative results, a new form of tube was devised.

This tube (see fig. 1) consists of a glass bulb, *a*, of 25 or 30 cc. capacity, sealed to a U-shaped glass tube, which is

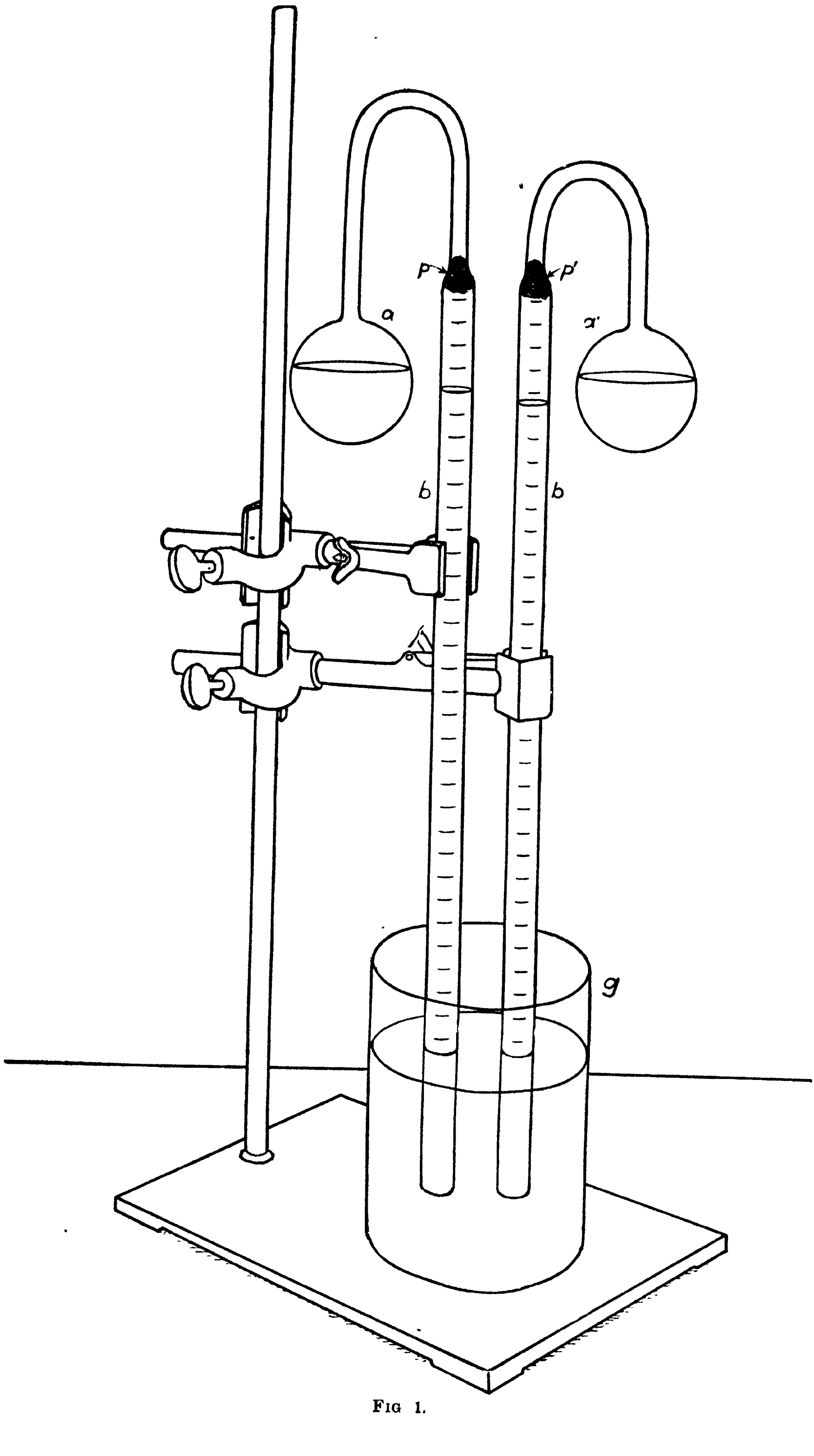

FIG 1.

sealed at its other end to a burette, *b*, graduated into divisions of $\frac{2}{10}$ of a cubic centimeter. The sugar solution to be tested is introduced by pouring the liquid into the long arm of the apparatus. The end of this arm is then stopped by the thumb, and the apparatus so inclined that the liquid is made to flow into the bulb. The long arm is then plugged with cotton, and the whole sterilized in the autoclave. In inoculating the broth the apparatus is inclined, after removal of the plug of cotton, until a small quantity of the nutrient fluid flows into the connecting neck; and the yeast or bacteria are introduced by means of a platinum loop sealed to the end of a long glass rod or tube. By bringing the apparatus to an upright position again the inoculated portion of broth is made to flow back into the bulb. If this is done carefully no nutrient fluid flows into the graduated arm. A piece of sterilized cotton is then pushed into the graduated arm until it reaches the point, *p*, where the U-connection is attached. The apparatus is then fixed in a clamp and the opening of the long arm placed in water from which air has been recently driven by boiling.

By means of a stiff rubber tube inserted far into the graduated arm, air is exhausted from this arm until water rises in it to a point previously determined. When results from two fermentation tubes are to be compared, this point is at such a level that the same amount of air intervenes in each tube between the top of the water column and the surface of the nutrient liquid in the bulb. Thus the error due to the expansion or contraction of different volumes of air, as the temperature rises or falls, is avoided. In adjusting the water columns to their zero points, the fermentation tubes are raised or lowered in the vessel of water at their base until the two columns of water are of the same height. The fermentation tubes are then placed in an incubator and kept at a nearly constant temperature.

This apparatus was found very satisfactory for comparison of gas production of two types of micro-organisms, since all gas formed is retained, readings are easily obtained, and the apparatus is so compact that the two tubes may easily be placed together in an incubator. Since the whole apparatus

consists of one solid piece of glass, there is no possibility of leakage of air.

In each of the five experiments, the results of which are given in the table below, two similar fermentation tubes were placed together, and one inoculated from a new race culture, the other from a check; and the two cultures supplying material for inoculation were grown under similar conditions long before the inoculation. In every case beef peptone broth, plus the desired per cent. of sugar, was used, and each bulb supplied with broth from the same lot and in the same quantity, always 20 cc. The same new race, one originating about November 1, 1903, was used in all five experiments.

TABLE I.

Date of beginning of experiment, 1905.	Medium.	Max. gas produced by new race, cc.	Max. gas produced by check, cc.	Temperature, degrees centigrade.	Time when maximum was attained.
May 10	1 % glucose broth	14.0	13 6	31–32	2d day.
May 20*	....	....	....	....	....
June 16	2 % saccharose broth	36.0	32.1	27–28	2d day.
June 27	2 % maltose	11.2	12 6	27–29	3d day.
July 8	2 % saccharose	39.1	39.3	23–25	4th day.

* In this experiment broth was used to which lactose had been added after a previous fermentation with *Coli communis*. Good growth was observed in the bulbs, but no gas was formed.

It will be seen from this table that the amount of gas produced by each type was nearly the same except in the two-per-cent. saccharose test of June 16. Several readings were made daily while fermentation was going on actively, and these show that fermentation began in both types at about the same time, rose at nearly the same rate, and reached its maximum at about the same time. After the maximum had been reached, the water in the graduated tube began to rise again, due to the resorption of gas by the water and the nutrient fluid. The rate of resorption was more rapid in the check than in the new race, in all except the one-per-cent. glucose experiment. Since the amount of absorbing surface is practically the same for each tube, and since the check formed as much or more of a pellicle likely to obstruct absorption than the new race, it is probable that in all ex-

cept the glucose experiment fermentation continued longer in the new race.

The amount of gas resorbed by each type approximately seventy-two hours after the maximum was reached is as follows:

TABLE II.

Date of experiment.	Medium.	New race, cc.	Parent type, cc.
May 10........	Glucose broth......	12.0	4.9
June 16........	Saccharose broth.......................	10.6	13.6
June 27........	Maltose broth..........................	5.1	8.0
July 8.........	Saccharose broth......................	21.7	22.4

The chief aim of these experiments was to compare two organisms; and, while every precaution was taken to keep the two under the same conditions during any one experiment, no especial pains were taken to have the temperature and reaction of medium exactly similar in the different tests. This may explain the discrepancy between the two saccharose tests of June 16 and July 8.

Summarizing, the new race seems to have a greater power of fermentation, but this was not the case in all experiments, nor to any marked extent.

In the experiments bearing on the relative resistance to drying and high temperatures of the two types, the same new race was used as in the fermentation experiments. To determine resistance to drying, cells were subjected to long drying at 35° C. to 40° C., to shorter drying at higher temperatures, or to both. Their resistance to higher moist temperatures was ascertained by exposing them in gelatin or liquefied agar to temperatures ranging from 50° C. to 70° C. for periods of from five to ten minutes. Throughout all these experiments the parent type as a check and new race were exposed to exactly similar conditions. Roll cultures were used for the most part, and a large number of cells sown in each tube.

Of eight dry-heat experiments, two showed small numbers of colonies in the new race, and none in the check. One of these two had been kept at 40° C. to 44° C. for twenty-seven days, the other under the same conditions for one month,

before plating. In a third, exposed to dry heat two days at 37° C., and later brought for a very short time to 50° C., both new race and check produced colonies, but the new race formed them in much greater numbers. Of the five other dry-heat experiments, the new race showed the better growth in four, but the difference was not great. In one, a two-day glycerin agar culture heated six and one-half hours at 43° C. to 45° C., the check showed five colonies, the new race none.

In several moist-heat experiments no growth occurred in either. For instance, no cells survived a temperature of 64° C. to 67½° C. for seven minutes in one experiment, or 70° C. for twenty seconds in another. In three moist-heat experiments growth occurred. In one, a thirteen-day glycerin agar culture heated in gelatin seven minutes at 54½° C. to 57½° C., the new race formed colonies while the check formed none. In a second experiment, in which a four-day culture was heated in glycerin agar to 55° C., there were two series of tubes, one exposed to the high temperature five minutes, the other ten minutes. In both series the new race colonies appeared more abundantly and earlier than in the check. In the ten-minute series only two colonies appeared in the check and these very late. In a third experiment, seven minutes in gelatin at a temperature of 50° C. to 53° C., both types formed colonies, but the new race produced the greater number.

Summarizing the positive experiments of both series, we find six in which the new race surpassed the check to a marked degree, four in which it surpassed but slightly, and one in which the check showed the better growth. These results indicate that the new race has a somewhat greater resistance to heat and drying than the type, in spite of the fact that spore production is greater in the type. As is known, however, yeast-cells not in the spore state may go into a very resistant condition, and it may be such cells which enable the race to withstand the unfavorable conditions. Microscopical examination of the roll cultures showed that only a small per cent. of the cells of either type survived.

As regards the liquefaction of wort gelatin, I have the results of but one experiment. The type and a new race about

two months old were inoculated in both acid and akaline wort gelatin in Miquel flasks, and an additional alkaline wort gelatin series was made in Petri dishes. Both flasks and plates were placed in the dark at room temperature. The results are found in the table given below:

TABLE III.

	After twenty-two days.		After twenty-seven days.	
	Acid wort gelatin.	Alkaline wort gelatin.	Acid wort gelatin.	Alkaline wort gelatin.
Miquel flasks:				
Parent type..	$\frac{1}{4}$ to $\frac{1}{5}$ liq......	No liq........	Wholly liq....	About $\frac{1}{8}$ liq.
New race....	Liquefied, but less than ck.	One large liq. colony, but less than on acid gel.....	About $\frac{8}{10}$ liq..	About $\frac{1}{2}$ liq.
Petri dishes:				
Parent type..	....	Much liq......	....	Much liq.
New race ...	....	No liq.	....	Little liq.

From this single experiment little can be deduced except that both types liquefy wort gelatin in nearly the same degree, any difference being in favor of the parent type, and that liquefaction proceeded more rapidly in acid than in alkaline wort gelatin.

The most of the experiments described above were made with a race originated about November 1, 1903. For the sake of confirmation several other new races similar to this one have been isolated from similar varying cells. I have at present in my laboratory four such races of *Saccharomyces anomalus*, ranging from one to three years and five months in age, all of which came from vegetative "sports," and one new race about two years old, arising from a spore. All of these retain their new characteristics apparently undiminished. Checks grown under parallel conditions clearly show that the persistence of the new characteristics is in no wise dependent on the medium or on other conditions of growth.

The results of my work on *Saccharomyces anomalus* may be summed up as follows:

1. Continued selection of cells of more than average size does not permanently modify the type.

2. Variations occur in this species, which, like mutations in higher plants, are capable of giving rise to races endowed

from the beginning with characteristics differing from those of the type. These variations are apparently independent of the immediate conditions of cultivation.

3. New races arising from these variations are characterized morphologically by cells abnormally elongated and tending to adhere in groups, and by a partial loss of the power of producing spores.

4. These morphological characteristics have persisted in cultures continued through three years and five months in a great variety of media, and a new race successfully competes with the parent stock when mixed with it in cultures.

5. Selection in the direction of further modifying the new races or of bringing them back to the type have alike failed to permanently alter the new characteristics.

6. There is evidence that the new races have a greater power of resisting heat and drying, a slightly greater power of fermenting sugars and a somewhat less power of liquefying wort gelatin than the type.

II.—EXPERIMENTS ON BACTERIA.

1. *Bacillus coli communis.*

In July, 1904, experiments were begun to determine whether the long filaments commonly seen in cultures of *Bacillus coli communis* transmit this character to offspring. A culture kindly supplied by Doctor Fernbach, of the Pasteur Institute, where this part of my work was begun, furnished material for the experiments. In order to secure absolute purity, a single normal cell was isolated at the beginning and experiments were conducted with the progeny of this cell.

A number of long filaments were isolated and failed to grow, but finally one was obtained which began to develop soon after isolation, and gave rise to a race differing morphologically and culturally from the type.

This July, 1904, race will be indicated by the letter A. The principal morphological characteristic of race A is its tendency to form long filaments in a much larger proportion than the type. (See photomicrographs, plate III. Figures 1 and 2 represent the parent type and the new race, respectively, both grown in bouillon under similar conditions.) Under some conditions the culture consists nearly

entirely of these long filaments. The tendency to elongation is more marked in newer cultures than in old, and is at its maximum a few hours after inoculation of tubes. After the culture is a day or two old, whether in hanging drops or test-tubes, its difference from the type becomes less marked, and is evidenced often only by the greater proportion of long filaments, which may be relatively few as compared with those of younger cultures, and, in some cases at least, by the greater length of the shorter filaments as compared with the normal. Young cultures of the race show less motility than the type, due probably to the greater length of filaments. Staining for flagella showed that the new race possesses flagella much like those of the type.

The new race is characterized by macroscopical peculiarities also, especially in plain bouillon cultures at room temperature. These cultures tend to become flocculent, the flocculi often adhering to the sides of the tubes or settling to the bottom, and leaving a comparatively clear liquid in the part of the culture between the pellicle and the sediment. In this respect the new race cultures present a striking contrast with the uniform cloudiness of the check tubes. Cultures of the new race on agar or in glucose bouillon show to the naked eye few or no differences from the type.

On gelatin the characteristics of the new race are strikingly different from those of the parent type. (See plate IV. Figures 3 and 4 represent colonies of parent stock and race A, respectively, grown in gelatin under similar conditions.) The race colonies often show an outgrowth of long filaments, New subcolonies are often formed on these outgrowing filaments forming an irregular group of colonies connected with a larger central one.

Both old and new races readily form pellicles. The pellicles are essentially alike on each, though in some cultures the new race formed pellicles which seemed slightly thicker than those of the type.

The stability of race A has been determined by a long series of subcultures on a great variety of media and under a considerable range of temperature. The filamentous character is more marked in liquid than on solid media, and at

room or refrigerator temperature than in the incubator. But whatever the conditions under which the new race is made to assume a more nearly normal aspect, it returns to the filamentous type when brought into conditions favoring this type; and the new characteristics have persisted unimpaired through a period of two years and eight months' cultivation.

In order to further ascertain the fixity of the new race a selection experiment was carried out. This experiment extended over several days and was conducted in drop cultures. In one series selections were made of the shortest elements of the new race, always selecting cells resembling the normal, and in the other series the longest filaments were selected in a similar manner. When a considerable growth had been obtained the shortest were again selected from the offspring of the short, and longest from the long.

These series were conducted through six selections of the longer filaments and six of the shorter. At the conclusion of the experiments there was no difference apparent between the two types, both having the usual appearance of the new race A. So it is evident that selection from either extreme of the curve of variability does not produce a race of different mean; there was neither accentuation of the peculiarity nor return to the original type.

Indol formation was tested in Dunham's peptone broth, about three months after the origin of race A. The color reaction was approximately the same for each type, and it is concluded that the new race forms indol in about the same degree as the parent form.

One of the most striking cultural characteristics of race A is its increased power of fermenting sugars.

In order to obtain more reliable quantitative results two new sorts of fermentation tubes were devised, one of which (tube No. 1) has already been described under the yeast experiments. In the other sort (tube No. 2) gas is formed under pressure exerted by a column of mercury. The mercury is poured into the apparatus until it enters the lower part of chamber *a* (fig. 2). Nutrient fluid containing the sugar to be fermented is then poured into chamber *a* through

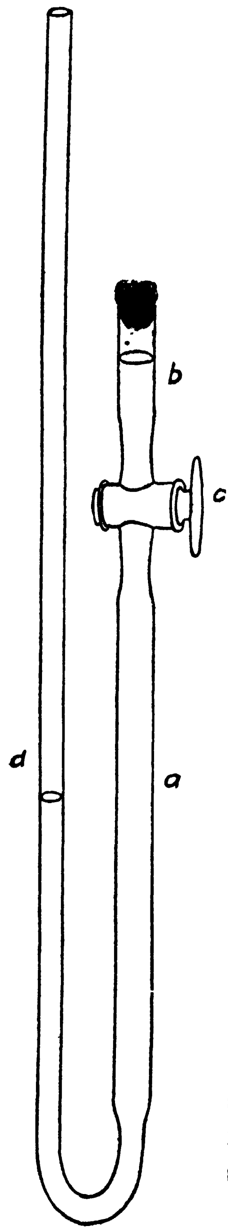

FIG. 2.

the tube *b*. Tube *b* is then plugged with cotton, and the whole apparatus sterilized in the autoclave. The stop-cock at *c* is left open during the sterilization, so that the expanding fluid may rise into tube *b*. After sterilization the stop-cock is closed before the liquid has sufficiently contracted to empty tube *b*. When the apparatus has cooled, the organisms to be tested are introduced into tube *b*, and the stop-cock opened enough to let a portion of the inoculated fluid enter chamber *a*. When gas is formed its pressure is recorded by the mercury column in tube *d*.

This apparatus also makes it possible to compare the growth of organisms in tube *b*, which is freely exposed to the air, with that in *a*, which is under nearly anaerobic conditions.

Three tests of the new race were compared with similar tests of the check in this apparatus, and the results are given in the table below.

In fermentation tube No. 1 gas is formed under negative pressure, and under nearly aerobic conditions. In the *B. coli*, as in the yeast experiments, tubes of this form were always used in pairs, with the new race in one and the check in the other. The same nutrient fluid was used for each, and in the same quantity, 20 cc., and inoculations were made from cultures previously grown under smilar conditions. In the test of July 17, 1905 (see table below), single filaments of the new race and of the type were isolated just before the test, and cultures made from the offspring of these cells were used for inoculation. This was done in order that the inoculated material of each type should

have been as nearly as possible under the same conditions before use.

Examination of the cultures remaining in the bulbs after the close of the experiment was frequently made, and no signs of contamination found.

In order to eliminate possible error due to differences in the fermentation tubes used, the tubes of a pair were sometimes changed after a test, and in a new test each was made to contain the organism previously grown in the other. Both tubes were kept in the incubator at the same temperature during an experiment, and observation was made at the same time of both, and without opening the inner glass door of the incubator.

A possible source of error lies in the fact that there was no maximum recorder in either type of tube. This source of error was largely eliminated by making frequent observations up to the time of maximum pressure.

In the table below, the figures in the second and third columns represent the maximum volume of gas formed in the fermentation tubes of type No. 1, and the the maximum pressure of gas recorded by the mercury column in type No. 2. The hours and average temperatures are reckoned from the time when the apparatus attained the temperature of the incubator until the pressure had reached its maximum.

TABLE IV. — Fermentation tube No. 2. Fermentation under pressure.

Beginning of experiment, 1904.	Mercury, cc.		Time, hours.		Average temperature.	Per cent. excess of A over check.	Medium.
	Type A..	Parent type.	Type A..	Parent type..			
Oct. 31..	18 60	16.50	70	69	28.6	12.7	2 % glucose broth.
Nov. 28..	17.15	13.87	125	118	28.0	23.6	Glucose broth about 1½.%.
Dec. 19..	15.85	14.15	150	189	29.0	12.0	Glucose broth about 1½ %.

TABLE V.—Fermentation tube No. 1. Fermentation under partial vacuum.

Beginning of experiment, 1905.	Gas, cc.		Time, hours.		Average temperature.	Per cent. excess of A over check.	Medium.
	Type A...	Parent type..	Type A...	Parent type..			
Jan. 7..	10.80	8.30	43	43	26.6	30.1	2% glucose broth.
Jan. 24..	11.20	8.40	20	20	32.4	33 3	1% glucose broth.
Apr. 19..	15.10	9.90	20	20	36 9	52.5	1% glucose broth.
Apr. 21..	13.60	10.20	18	18	36 0	33.3	1% glucose broth.
Apr. 28..	14 10	10.80	33	33	36 9	30.6	2% lactose broth.
May 5..	14 35	10.60	15	7	37 2	35 4	1% glucose broth.
Jun. 16..	15.20	9.10	24	24	35 9	67 0	2% saccharose broth
May 26..	11 90	5.30	46	23	37.7	124.5	2% saccharose broth
Jun. 27..	13 50	8 20	14	14	36 6	64 6	2% maltose broth.
Jul. 17..	8.50	5.80	17	9	35.5	46 6	2% glucose broth.
Dec. 5..	12.90	11.60	20	24	37.3	11.2	1% glucose broth.

It is seen from the above table that the new race constantly shows a higher maximum gas pressure than the parent type. This is true of all sugars used, though the per cent. of excess is greater in the saccharose and maltose tests than in the glucose. In about half the experiments the maximum pressure was reached at the same time in each type of *B. coli*, while in the others sometimes the one and sometimes the other type reached its maximum first. But there seems to be no correlation between the relative times required to reach the maximum and the per cent. of excess gas pressure in the new type. There is further no constant relation between the temperature and the per cent. of excess gas pressure of the new race.

The gas formed in Smith fermentation tubes by race A and the check was tested and the per cent. of CO_2 found to be approximately the same for each.

Glucose broth cultures inoculated with race A and the check were tested with Fehling's solution after fifty days' growth—about seven days at incubator and about forty-three days at room temperature. Both gave a positive glucose reaction, and in about the same degree.

On Endo agar both race and check produced the characteristic reddening of the medium, and there was no marked difference in the amount of color.

To determine the relative sensibility of the new race and

the parent type to agglutinins, cultures were tested with the serum of two rabbits, the one immunized with gradually increasing doses of new race A, the other immunized in a similar way with the parent type. In both kinds of serum dilutions were made ranging from 1 in 4000 to 1 in 13,000, and in the rabbit immunized with race A, as high as 1 in 21,000. In all these dilutions, the parent race showed decidedly more sensitiveness to agglutinins when fresh broth cultures were used. Agar cultures showed a less decided difference. Tests were made both microscopically and macroscopically; controls were kept, to eliminate error due to spontaneous clumping, and, in order to eliminate the personal equation I submitted the results to two other persons, experienced observers, who independently confirmed my judgment. Many series of tests were made, only one of which I give in the table below. The test was made with the serum of a rabbit inoculated with nine successive inoculations of cultures of race A, the inoculation period extending over twenty-five days and ending with a dose of 3.5 cc. of a six-day broth culture.

TABLE V.

Dilution.	Result after 35–50 minutes.		Result after 2 hours.		Result after 5½ hours.	
	Race A.	Ck.	Race A.	Ck.	Race A.	Ck.
1–14,000.........	?	+	?	+	+	+
1–21,000.........	?	+	?	+	+	+
1–28,000.........	?	?	?	?	?	Slightly?

Thus it is evident that the parent type is more easily agglutinated than the race, whether the agglutinating serum is obtained from an animal immunized to the race or one immunized to the check. This difference between the new type and check may possibly be referred to the more filamentous character of the race, and a consequent less motility. While the difference in agglutination is decided in broth cultures, it is doubtful in emulsions of agar cultures; and it will be remembered that in agar the filamentous character of the race is less pronounced.

The lesions in the inoculated rabbits were insignificant, and there was no decided difference between race and type.

In order to confirm previous results and to ascertain more exactly the sort of variation leading to these new races and the conditions under which they arise, a new series of experiments was undertaken during the summer of 1905. It soon became apparent that variations leading to permanent races are not so common as the early success of the experiments of 1904 had led me to suppose. For nearly six weeks experiments were conducted before a second permanent race was obtained. Under a great variety of conditions, long filaments such as had formed the starting-point of race A were selected, but, on being isolated, they either failed to grow or reverted to the type. Various media, principally plain and glucose broth, were used, in all of which the long filaments were found, and isolations were generally made from young test-tube or hanging drop cultures.

During the period mentioned about 140 filaments of various character were isolated from the original type of *B. coli*, which was the parent of race A (*B. coli*, type I), all except one without success. From another stock of *B. coli* which I isolated from feces (*B. coli*, type II) about fifty more such isolations were made, principally under conditions which had proved successful in obtaining race A, and of these only one new race was obtained. In all, over 190 isolations in long filaments were made, from which only two new races were obtained.

In a number of the above isolations I recorded only failure or success in obtaining a new race, but in 95 I kept a complete record, and the results were as follows: Out of 52 isolations from the original type, *B. coli* I, 36 failed to grow at all, 6 partially developed and failed to grow further, and 9 grew well, but reverted to the parent type, and 1 formed a permanent new race. Of 43 isolations from *B. coli*, type II, 29 failed to grow, 5 showed limited growth, and 8 reverted to the type, and 1 formed a permanent new race. The 95 isolations fairly represent the whole number of attempts made under the best conditions of temperature and medium. The two filaments which grew into permanent new races showed no characteristics differing from the majority found in unsuccessful attempts.

Thus of 95 filaments, approximately 18 per cent. reverted to the parent type, 11 per cent. partially developed, and 68 per cent. failed to grow at all. Two, or about 2 per cent., grew into permanent new races. Including the 11 per cent., the most of which developed only a few threads, with the 68 per cent., we have 79 per cent. which either failed to grow or developed only slightly. Including all filaments isolated in this series, we have of the total number of over 190 filaments only 2, or about one per cent., which formed permanent new races. The number of reversions to type recorded may be too large, because in some experiments selection was made from very young cultures, when there is a greater tendency for normal rods to adhere in filaments than in cultures a few hours older; and it may be that occasionally a filament was selected which was not a variation, but owed its length to its early age merely. In a large proportion of cases, isolations were made of single normal cells under the same conditions to serve as checks. Of these fully eighty per cent. developed. In fact, when these cells were isolated from recent vigorous cultures, as was the case with the larger number of variation isolations, they rarely failed to grow. So the failure of the varitions to grow cannot be laid to the conditions of cultivation or to injury suffered in the process of isolation. It was found that if non-motile filaments were isolated they almost invariably failed to develop further; so, during the latter part of the series of experiments, I isolated for the most part motile filaments alone.

In order to eliminate possible inhibitory effects of concentration of medium in hanging drops an additional series of isolations was made in which long filaments were drawn into capillary tubes immediately after isolation. There were about ten in this series and the results obtained were essentially like those observed in hanging drops.

Among the filaments which reverted to the normal type some produced a progeny which for a time showed an abnormally large number of long filaments, and some of those which only partially developed produced in a few cases four to six long filaments before growth ceased. There seems to

be an almost complete series of gradations between those filaments which showed no growth, and those which immediately reverted to the type. There were, first, filaments which exhibited no growth at all, though in many cases they showed considerable motility after isolation; second, those which merely increased somewhat in length; third, those which produced several filaments or short rods, then ceased to grow further; fourth, those which grew at once into vigorous cultures, but during the first generation showed an abnormally large number of long filaments; and finally those which grew into normal cultures without any peculiarities. The variations which produced permanent new races seem to lie between the third and fourth gradations.

Some of the filaments which partially developed showed some interesting phenomena. The motile filament would divide and produce perhaps one or two long motile filaments, one or two non-motile ones, and perhaps two short, very motile rods. I have found these short rods motile twenty-four hours after the original isolation was made. Their failure to grow cannot be attributed to conditions of culture, since, close beside them, in the same medium and under the same cover-glass, single normal cells of apparently no greater motility rapidly developed numerous offspring.

The new race which I originated during the summer of 1905 from *B. coli*, type I (new race H), exhibits characteristics similar to those of race A, but more closely approaches the type. It has been cultivated nineteen months, on various media, but neither reverts to the type nor approaches race A. I have made three tests of its power of fermentation, using fermentation tubes of the type No. 2. In the first test, made soon after its origin, race H produced a lower maximum than the type. It was then passed through four subcultures, and a second test made five days after the first. It then showed a higher maximum than the type. About four months later it was tested again, and this time showed a maximum 13.7 per cent. greater than the type.

The third new race (race Y), which I obtained in the summer of 1905 from *B. coli*, type II, shows characteristics similar to the other two, but differs less from the type than A and

more than H. While H shows little microscopical difference from its type, Y, like A, tends to form flocculi in bouillon. H has less tendency to form very long filaments than either A or Y, but the average length is much greater than that of the type. I have at present all three of these new races growing in my laboratory, each with a check taken from the type culture at the time when the new race began.

Another sort of new race, characterized by a nearly complete loss of motility, was obtained from an agar culture of the same *B. coli*, type I, from which new races A and H had come. In the water of condensation from this agar culture a series of single cells were isolated, each in a separate droplet. A number of these grew into normal motile cultures; but one of them, which at the time of isolation had the appearance of a normal cell, gave rise to offspring almost wholly non-motile. These did not differ in any other respect from type cells, except that there was a tendency to form groups of short chains lying parallel to one another; and the tendency to adhere in short filaments, seen in all very young cultures, persisted longer in this new race; both tendencies are perhaps due to the loss of motility.

In a large hanging drop from a fresh culture of this non-motile race a few motile cells could usually be seen, and it was found that repeated selections of these motile cells produced cultures of somewhat increased motility. On the other hand, six successive selections of non-motile cells from the original non-motile race has given a type which remains practically non-motile after a period of cultivation extending over nineteen months. Over a year after its origin selections from the very few non-motile cells appearing in cultures of this race have failed to produce a motile type.

Tests have been made of the vigor of growth and the power of fermentation of this non-motile race, and it apparently equals the parent type in these respects. An attempt to restore its motility by repeated transfers of fresh cultures grown under favorable conditions of medium and temperature gave negative results, though seven such transfers were made during a period of three days. Similar transfers of the pa-

rent type under parallel conditions resulted in a comparatively actively motile culture.

Partial loss of motility is a not uncommon phenomenon in the *Colon* group of bacteria, and is often the immediate result of the environment. But the observations described above cannot be all explained as the result of conditions of growth; for the non-motile strains apparently appeared suddenly, and remained non-motile through many generations and under a great variety of conditions; and it seems more probable that we have to do with variations somewhat similar in character to those of race A. But the non-motile types seem less stable and more easily influenced by selection than the type varying morphologically, and it is probable that such non-motile types will in time revert to the parent stock unless kept up by occasional selection.

SUMMARY OF EXPERIMENTS ON COLI COMMUNIS.

1. Variations arise in *Bacillus coli communis*, which, like those of *Saccharomyces anomalus*, may give rise to races exhibiting permanent morphological characteristics not possessed by the type.

2. These variations arise suddenly and apparently independently of conditions of cultivation; and are to be compared with mutants observed in higher plants.

3. They show, in general, a tendency to diminished rapidity of growth at the beginning, but, having once begun to develop, they produce as a rule cultures as vigorous as the normal.

4. They are of different types, and the new races arising from them may be characterized by an abnormal tendency to produce long filaments, or by a nearly complete loss of motility.

5. These new races vary in the degree of their deviation from the type and in their stability. While some apparently require more than one selection to preserve their fixity, others have been constant from the first selection over a period of two years and eight months.

6. One new race further differs from the type in exhibiting an increasing power of fermenting sugars, and a partial loss of sensitiveness to agglutinating serums.

2. Bacillus typhosus.

In the summer of 1904 a series of selections were made of the long threads occurring in cultures of *Bacillus typhosus*, experiments similar to those conducted with *B. coli communis*, and carried on at the same time and under the same conditions. A culture obtained from the collection of the Pasteur Institute was used, and the progeny of a single cell isolated at the beginning furnished material for selection.

A large number of abnormally long filaments were isolated, several of which developed cultures exhibiting more than the normal proportions of long filaments. Of these all but one soon reverted to the type. This one showed the new characteristics for some time and through a number of subcultures; but, being occupied with work on other organisms, I did not follow the history of this race carefully, and it finally died out.

In the summer and autumn of 1905 I resumed these experiments with a new culture of typhoid obtained from Parke, Davis & Co. September 26 I isolated four cells of normal appearance in four separate droplets; three of these devel oped normal offspring, but one gave rise to a new race characterized by long filaments in much greater proportion than the normal. Colonies on gelatin were much different from those of the parent type cultivated under similar conditions. They were very irregular in form, owing to the outgrowth of long filaments, which formed subcolonies and gave the whole the appearance of a group of small colonies. Bands of parallel thread projected out from a colony, and sometimes curled into peculiar spiral arrangements, owing probably to some resistance met with in their outward progress. Fifty-three days after its origin this culture had apparently reverted to the type.

At the same time that the above typhoid race was isolated, a considerable number of isolations of long threads were made; but all either failed to grow, or, after showing for a time an increased proportion of long filaments, reverted to the type.

These experiments are incomplete, but from them it appears that variations appear in *B. typhosus*, which, when iso-

lated, produce new races similar to those of *B. coli communis*, but of comparatively less stability. Judging from the *B. coli* experiments, however, it is at least possible that by continued selection of long threads one would finally obtain a variation which would produce a permanent new race. In my cultures of *Bacillus typhosus* there was a greater tendency to produce long chains than in *B. coli communis*. As is well known, unselected cultures of *B typhosus* are not uncommonly met with which show a marked tendency to form long filaments, a tendency partially dependent on the medium employed. For instance, in some of my experiments *B. typhosus* showed a marked tendency to form long filaments when grown on agar containing malachite green in the proportion of 1 to 12,000. On being transferred to broth, these cultures reverted to the normal; but the elongated tendency persisted to a slight extent in the first broth culture.

2. *Bacillus megatherium* (?).

From gum occurring in cane juice obtained from Louisiana I isolated, in December, 1903, a large, plump, motile bacillus, characterized by granular contents, and readily forming spores. From cultures of this bacillus, probably *B. megatherium*, I made many attempts to obtain an asporogenous race by selection. However large the proportion of cells which form spores in hanging drops, there are usually some few which remain motile and sporeless. Scores of those sporeless cells were isolated and cultures obtained from them, usually with negative results as regards obtaining races with diminished spore-forming power. About March 1, 1904, a single sporeless rod of this type was isolated, the offspring of which remained sporeless, though cultivated under conditions under which the type produced spores abundantly. Granules somewhat resembling early stages of spore formation appeared frequently in cells of this race, but no mature spores. At various times during the two months following its origin, this race was compared with the check in broth and on agar. The check formed spores, while the race remained sporeless. Cultures of the sporeless race, taken soon after its origin, and of the check, were sealed in test-tubes. After one year

and nine months the check was found to be still alive, but the new race was no longer viable.

In the summer of 1904 experiments were renewed in the attempt to confirm earlier results, but, though experiments were continued through several weeks, and many series of vegetative rods isolated, all of them reverted to the spore-forming type. These attempts were renewed in the autumn of the same year, and again in the summer of 1905, but with uniformly negative results. The original asporogenous culture of 1904 was continued through many subcultures, but finally died.

While no final conclusions can be founded on the results of one successful experiment, there is good evidence from this experiment that asporogenous races of bacteria, retaining their characteristics for weeks at least, may be obtained by selection of certain vegetative cells. But from the large proportion of failures to obtain new races by the selection of sporeless cells, it is evident that variations which result in asporogenous types are rarely met with.

GENERAL SUMMARY.

In surveying the field in which these experiments lie, one is at once impressed by the similarity between the new races observed here and those arising in higher plants by mutation.

We have in both the sudden appearance of a new type with full-fledged characters arising independently of natural selection, and apparently independently of immediate environment. Successive generations of yeasts or bacteria doubtless find their counterpart in successive cell generations in organs of higher plants; and new races arising among them are to be compared with sports arising vegetatively in multicellular organisms.

While it appears that such variations are much more common among micro-organisms than in higher plants, it may well be that this difference is only apparent, and that there may be very many cell variations in higher plant organs which undergo the same fate as that of hundreds of yeast and bacteria cells which I isolated in my experiments, and either fail to develop or revert to the normal type. There

may be some parallelism between the comparatively few successful new types which I obtained and the sports which become apparent in higher organisms. Whether there is any innate connection generally between a temporarily diminished vegetative activity and heterogenesis, as seemed to be the case with certain of the micro-organisms in my experiments, is, of course, only a matter of conjecture.

We have further this important difference between cell generations in unicellular and higher multicellular plants: the possibility of isolating a single varying cell of the former type alone, a matter which has a bearing on the question whether new races arise among micro-organisms from single varying cells under natural conditions.

The comparative constancy of species of yeasts or bacteria when kept under unvarying conditions argues against the probability that varying cells of the sort which I isolated commonly produce progeny which successfully compete with the parent culture. It will be remembered, too, that a large proportion of these varying cells lack vitality, and in the case of the yeast the growth of the new race is often very slow, until it abandons the more filamentous condition and partially reverts to the type. But there are many chances of accidental isolation of single cells of unicellular plants and in an environment which favors their development; and, once started, they may behave as most of my races did and become as vigorous as the type, and, as in one race tested, they may be capable of competing with the parent race in mixed cultures. Again, there is evidence from the heating and drying experiments conducted on a new race of *Saccharomyces anomalus* that a greater resistance to unfavorable natural conditions may be correlated with a morphological variation. This may be a factor of weight in the origin of new races among micro-organisms, subjected, as many of them are, to great vicissitudes in environment.

So, when we consider that physiological characteristics may be correlated with the morphological, as in the case of the increased power of fermentation in race A of *B. coli communis*, and that we may well have variations characterized by physiological characteristics alone, it seems well within

the range of probabilities that mutations, if such they are, have played some part in the evolution of species of micro-organisms differing physiologically as well as morphologically from the ancestral type. We may have here a factor in the origin or increased virulence of some pathogenic types.

It is suggested by Meyer* that such variations among micro-organisms may be simply a matter of atavism, and Will refers his yeast races to polymorphism. But in experiments on higher organisms as well we often meet with the same difficulty of deciding whether we have to do with the appearance of a new character or the reappearance of a latent one; and in the case of both higher and lower plants only long-continued experiments on many different types can decide the matter. If mutations occur among the cells of higher plants, we would expect, on *a priori* grounds, to find them in the lower also, and perhaps more frequently in these less differentiated and more plastic types.

Fisher (1897) inclines to the view that new races among micro-organisms are to be referred to degeneration. In favor of this view is the diminished vitality of many cells similar to those which originated new races in my experiments, and the slow early growth and diminished spore production of some of the yeast races. But, with the possible exception of *B. coli* Y the new races described above are, when once begun, as vigorous vegetatively as the type, and in the *B. coli* races A, H and Y the offspring of the varying cells early became as vigorous, or nearly as vigorous, as those of the type. Further, these variations appear in relatively few cells and under apparently optimum conditions of growth, so they can hardly be referred to immediate conditions, unfavorable or otherwise, acting on the whole culture.

METHOD OF ISOLATION.†

The essential parts of the apparatus used in the isolations described above consist of an ordinary 1x3 inch glass slip, to which are cemented pieces of glass in such a way as to form a box open at the top and one end (see *b*, fig. 3). The

* *Vide supra.*

†A short preliminary description of this method was published in The Journal of the Kansas Medical Society, of November, 1904.

dimensions found most convenient for this box are 40 mm. long by 25 mm. wide by 18 mm. high, though various other dimensions have been successfully used. The sides of the box are lined with filter-paper extending nearly to the top and projecting a few millimeters beyond the open end. A small rod may be inserted at the base of the open end to strengthen the apparatus.

Before making isolations, the filter-paper is thoroughly wet, and a 25x40 mm. cover-glass, previously well cleaned, is sterilized in the flame and placed on the box, to the upper edges of which vaseline has been previously applied. On the sterile under surface of the cover-glass a drop or two of the sterile nutrient fluid to be used is placed by means of a sterilized platinum loop, and near it a drop of the culture containing the organisms to be isolated. The whole is then placed on the stage of the microscope, *a*. A capillary pipette, *b*, is then made by drawing out in the flame a thin-walled glass tube, 8 to 10 cm. in length and about 4 mm. in diameter, in such a way that one end becomes a fine tube, with walls as thin as possible. Holding the thicker end of this tube in one hand and the capillary end with sterilized forceps in the other, the capillary tube is again drawn out over a very small flame, and, just at the moment of drawing, a turn may be given with the forceps so as to form a tip, curved nearly at right angles with the rest of the tube, or the capillary tip may be made straight and afterward bent in the heat of the flame. It is important to have the aperture of this curved tip very small, especially for work with bacteria. I have used pipettes of such dimensions that the opening would admit the smaller yeast cells, but not the larger. If the pipettes are made much smaller than this, capillarity may be so great as to prevent the discharge of liquid from the opening. It is often convenient to make a number of these pipettes, sterilize them in the hot-air sterilizer, and keep them in sterile receptacles ready for use.

In the latest type of this apparatus the thicker part of the pipette is held with a brass holder, clamped on the left side of the stage. The box, held in the mechanical stage with its open end towards the pipette holder, is adjusted so that the

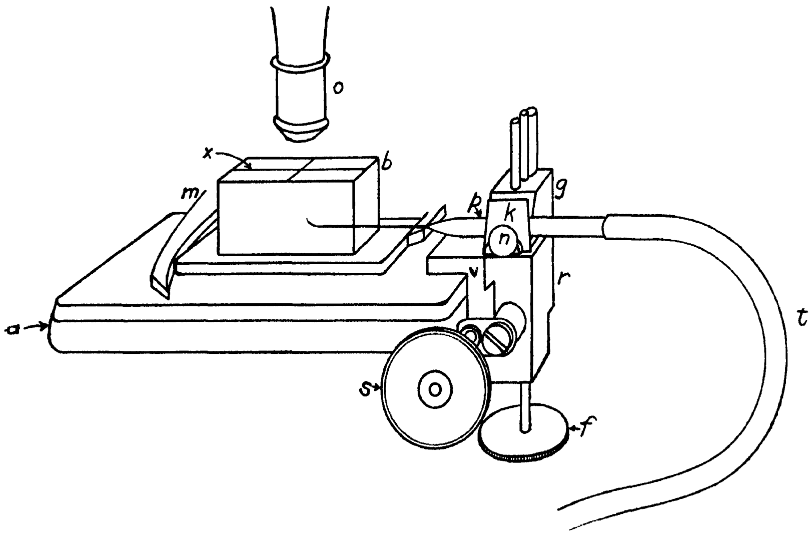

FIG. 3.

cross-lines, x, on the cover are in the center of the field. The pipette is then adjusted by moving it in or out in the groove at the side of g, or laterally by turning the screw, s, which moves parts r and g of the holder. Adjustment is continued until the pipette point is nearly in the center of the field of the microscope. If higher powers are to be used, I usually adjust the pipette under the two-thirds objective first, finally placing it so that its tip is in focus near the center of the field to be used. Finer adjustments may be accomplished laterally by means of screw, s, and in the other direction by a slight movement of the nose-piece holding the objectives. The pipette, together with the parts g, k, and n, holding it, is raised or lowered by means of an adjustment screw, f. The part v is immovable, and remains clamped to the stage of the microscope.

When the pipette is in position it is fixed by the set-screw, n, which tightens clamp k. By means of the mechanical stage that portion of the cover bearing the sterile drop of medium is now brought into the field, the tip of the pipette raised into it and held until it partially fills, or the pipette may be filled before it is placed in the holder by touching its tip to a drop of nutrient fluid held in a sterile platinum loop.

After filling, the pipette is caused to descend and the culture drop brought into the field. The tip of the pipette, which meanwhile is kept in view, is raised until it comes into contact with the micro-organism to be isolated. This immediately enters the pipette by means of capillarity, often in company with other cells; though I have often succeeded in withdrawing the pipette quickly enough to secure only the cell desired. After securing the cells, the cover is moved by means of the mechanical stage until the tip of the pipette can be brought into contact with an unoccupied part of the cover, where its contents are discharged. The discharge is accomplished by blowing gently into a rubber tube, *t*, one end of which is attached to the outer end of the pipette while the other is held in the mouth of the observer. Should there be other cells with the one selected, I usually make a series of droplets with the contents of the pipette, in one of which the cell desired appears alone or with so few other cells that isolation is generally easy at a second attempt. When motile organisms are to be isolated I often place a sterile drop beside the culture drop in such a position that the two drops are in contact at a portion of their circumference. The more active bacteria will soon move into the new drop where they may be taken up by the pipette.

Once isolated, the micro-organism may be picked up and carried to any part of the cover, or, if desired, a fresh sterile cover may be placed on the box and the single cell deposited on it, or, finally, it may be received into a drop on a platinum loop and transferred to a test-tube. In my work I have usually left the isolated cells on the same cover and kept them in view during their development, but in some cases I have drawn the isolated cell well back into the pipette, sealed both ends of the pipette, and placed it in the incubator for development. Many isolations may be made on the surface of one large cover. No difficulty is experienced from the running together of droplets if, just before sterilizing, the cover is rubbed with a piece of chamois skin, or with a cloth having the least trace of vaseline on it. Care must be taken in sterilizing not to leave the cover in the flame long enough to burn off all the vaseline.

After the isolations have been made the cover is sealed over a hollow slide by means of vaseline. I prefer slides with shallow hollows for this, and find that if the hollows are breathed on just before sealing the cover, sufficient moisture will condense on the slide to keep the culture in a saturated atmosphere.

After the cover is safely sealed on the hollow slide the isolations may be examined with higher powers and better light, and any droplets marked so that they may easily be found at later examination. To accomplish this, I generally dip a very fine capillary rod in Brunswick black and with it make one or more dots or lines on the cover above the droplet to be marked. This is easily done under the two-thirds objective after a little practice. It is very helpful to make a large cross with Brunswick black or India ink on the cover before isolating, since the lines serve as a guide for locating droplets. Since the apparatus allows one to control the position of the droplets accurately, they may be arranged thus:

	A	B	C	D
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

and any droplet recorded by letter and number.

In putting away the culture to develop, one should, of course, put it in a protected place, and avoid placing it so that the cover will be exposed to a lower temperature than the slide beneath, else drops of moisture may condense on the cover and cause the droplets to run together. I use for the most part a special slide with a shallow concavity much larger than that of the ordinary type.

I seldom meet with difficulty from the drying up of droplets during isolation, if the filter-paper, lining the sides of the box, is well wetted before beginning; but, as an additional precaution against both desiccation and contamination, one may nearly close the open end of the box with wetted filter-paper after the pipette has been introduced. If the organism isolated is sensitive to the least concentration of the medium through desiccation, it is well to add fresh sterile nutrient fluid just before sealing.

When the cultures have grown, cells may be removed by means of the same apparatus to a new cover or test-tube; or, if there is room, they may be reselected on the same cover. I have experienced little difficulty from contamination. For many months I have carried on experiments with yeasts and bacteria at the same time, and contamination of the one by the other has been almost unknown, and drops not inoculated uniformly remain sterile. So it seems improbable that yeasts are ever contaminated with other yeasts, or bacteria with bacteria. Even if one could not observe the origin of the yeast and *B. coli* variations, for instance, and follow their first development after isolation, one could hardly attribute the origin of these new races to contamination, considering the small chance that an organism should enter which has so many characteristics in common with the parent culture.

I have described above the later and more elaborate apparatus for isolating micro-organisms. In routine work, unless an objective of higher power than a one-sixth is to be used, I often employ the simpler method first devised. The pipette holder is here dispensed with, and the position of the glass box reversed so that its open end is toward the right. The right hand, steadied by the stage, holds the pipette, and the fine adjustment of the microscope and the mechanical stage are operated by the thumb and second finger of the left. This method has the advantage of simplicity and speed, especially in the matter of changing pipettes; but requires some steadiness of hand and considerable practice in manipulation; for the operation once begun, one cannot lose sight of the tip of the pipette without risking contamination. I find little difficulty, however, in working under the one-fourth and one-sixth objectives with one-inch ocular by this free-hand method.

Besides the work of isolating variations, I have frequently used the above methods as a substitute for plate cultures in isolating organisms. I have successfully isolated single spores of fungi, single cells of algæ, various yeasts, and many bacteria, including *Streptococcus*, from pus. I have found little difficulty in obtaining colonies of amœbæ or infusoria grown from single individuals. The method has some ad-

vantage over the ordinary plate method, in that the process requires much less time, and one can follow the development of a micro-organism from the first, and be sure that the subsequent colony comes from the cell originally isolated. In old cultures a considerable proportion of cells may be dead in the material from which such isolations are made, so it is sometimes necessary to isolate a considerable number of them to obtain a single successful growth. It is possible to work with relatively small quantities of medium in making isolations, and I have obtained sufficient sterile serum for this purpose from small blister made on the hand. It seems probable by this method of isolation something may be done in the way of isolating organisms which are with difficulty handled by ordinary methods. I have as yet made but few experiments in this direction.

The method has been used by several of my students as well as by myself, and they have found it not difficult to acquire. In this description I have omitted many details which would require too much space to describe, but knowledge of these are soon acquired by the experimenter.

I take this opportunity of recognizing the very material assistance rendered me by my students in this work, especially Mr. A. H. Sellards, who has cooperated in many ways, and Mr. Montrose Burrows, who assisted much in designing the pipette holder described above. I wish to acknowledge also the kindness of Doctor Fernbach and other workers at the Pasteur Institute, who placed at my disposal cultures and other laboratory facilities during my work in Paris, in the summer of 1904.

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KANSAS UNIVERSITY SCIENCE BULLETIN.

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SOME RESULTS OF DESULTORY COLLECTING OF INSECTS IN KANSAS AND COLORADO.

BY ELBERT S. TUCKER.

IN spite of the fact that a person may be regularly employed in entomological work, he may not have opportunities to do personal collecting of insects any more than one who is otherwise engaged. When one is steadily occupied throughout every working-day, only such time as comes outside of prescribed hours of work permits the undertaking of separate or distinct pursuits of individual concern or diversion. Nevertheless, a great deal can be accomplished in any line by improving odd periods of leisure. One advantage which entomology has over other studies in natural history is that collections of specimens can be made at night as readily as by day. Much spare time that can be utilized for day collecting is afforded during holidays, vacations, excursions or on visits; in fact, occasions frequently occur which invite the insect collector to go forth with net and bottles. Intervals of even an hour can be advantageously spent in this manner. Unlike the hunter or fisherman, he need not seek the wildest haunts in nature, for an abundance of varied forms generally await him ready at hand whether he is situated in country or city. Records of local collecting done even in a small way often have a value proportionate to those of more extensive collecting; besides, additional merit may be rendered if detailed particulars are given.

Little by little, here and there, whenever a chance is offered, by day or by night, considerable material will be accumulated in the course of a year or two by persistent collecting

of insects. The results of such efforts will mainly comprise an assortment of widely diversified forms rather than many representatives of any particular group, unless attention is devoted exclusively to certain kinds. No matter how disconnected one's operations may become regarding place, time or other conditions in collecting, the final outcome, through skilful classification of the specimens, can be presented with system and order.

What I consider as my personal collecting, to which all my records pertain, unless in reference to metatypes of two newly described species, has been done aside from any connection with the expeditions undertaken by Dr. F. H. Snow for the University of Kansas. Thus restricted, my efforts have been confined to portions of Kansas and Colorado, with the advantage, of course, in favor of my home locality, where night work was engaged in to a great extent. Only spare time in any instance has been thus employed. All of my specimens, with few exceptions in cases of common duplicates, have been added to the entomological collections of the University of Kansas, and from those that are identified I have prepared the following lists of their names, together with records regarding the capture of each species.

LIST OF HEMIPTERA-HETEROPTERA.

Wherever I have collected these insects, rich results were obtained, even at home. The greater part of my collecting in Colorado was done during a visit of six weeks, in the months of July and August, 1894, principally in Colorado Springs. All other collecting in this state has been done subsequently on trips of short duration. A list of the determinations of species in the order Hemiptera from my first collection in Colorado, and also some undetermined specimens, since all could not be readily identified at the time, were furnished to Profs. C. P. Gillette and C. F. Baker, at their request, by Mr. W. A. Snow, of the University of Kansas, thereby granting them the benefit of the results of study for incorporation in their work entitled "A Preliminary List of the Hemiptera of Colorado," which appeared as Bulletin No. 31 of the Colorado Agricultural Experiment Station. The extent to which

my specimens in the Heteroptera alone were reported upon in this work is shown in the records of thirty species, where credit is given me in each case as the collector. In this number six capsids were described as new to science. The enumeration of all these species again, including all records of captures up to the present time, is embodied in my list herewith, which includes the names and data of twenty-eight other species taken in Colorado. Of this additional number, four species at least are new to the Colorado list, one being only now described. Another species whose identification now remains in doubt may eventually prove to be new also

In respect to the Kansas part of the collecting, there are forty-eight species new to the state list which was begun by Prof. E. A. Popenoe, in Transactions of the Kansas Academy of Science, volume IX, pages 62, 63, and recently enlarged by Mr. F. F. Crevecœur, *loc. cit.*, volume XIX, pages 232–234.

Of the total number of species listed, nineteen were collected in both Kansas and Colorado, the number for Kansas alone being 108 species.

Many of the determinations cited in my list have been made by myself in the regular course of museum work, by comparison of the specimens in hand with named specimens already in the University collection. When this course was not possible for want of named material, or in cases of doubt, examples of the specimens being studied were submitted to eminent authorities according to their preference for certain groups; hence acknowledgments are due to Mr. E. P. Van Duzee, Mr. Otto Heidemann, and Mr. J. R. de la Torre Bueno, for their generous aid toward the entomological museum of the University of Kansas, to each of whom I am also indebted for personal favors.

The catalogue of Lethierry and Severin was first used as a guide for the arrangement of the Heteroptera, so far as that work treats of the families, although more recent changes in nomenclature are adopted. For advice concerning the nomenclature and arrangement of generic and specific names in the families omitted in this work, I was forced to seek special authorities. Mr. Heidemann kindly revised and arranged my list of the Capsidæ, and likewise in regard to the water-

bugs, as well as in other matters, I was generously aided by Mr. de la Torre Bueno. However, since the appearance of Mr. G. W. Kirkaldy's "List of the Genera of the Pagiopodous Hemiptera-Heteroptera," the positions of those families which he treats have been rearranged to conform with the rank in which he regards them.

EXPLANATION.—The figures 31 in parentheses (31) refer to personal credits, whether in part or in full, which are acknowledged in Bulletin 31, Colorado Agricultural Experiment Station.

Family PENTATOMIDÆ.
(Subfamily *Corimelæninæ.*)

Corimelæna nitiduloides Wolff. Kansas, Douglas county; May, July.—Colorado, Denver; August.

(Subfamily *Scutellerinæ.*)

Homæmus æneifrons Say. Colorado, Manitou; July (31).
bijugis Uhl. Colorado, Manitou; July.
grammicus Wolff. Colorado, Colorado Springs, August (31).

(Subfamily *Cydninæ.*)

Cydnus obliquus Uhl. Kansas, Douglas county; April. New to the Kansas list.

Pangæus uhleri Sign. Kansas, Douglas county; May, June, July, October. New to Kansas.

Amnestus pusillus Uhl. Kansas, Douglas county; May, at electric light on streets; July, at electric light on river bridge.

(Subfamily *Pentatominæ.*)

Brochymena quadripustulata Fab. Kansas, Douglas county; April; August, taken in thicket at Wakarusa river; August, on mulberry tree close to colony of web-worms; October. New to Kansas.

Peribalus limbolarius Stal. Kansas, Douglas county; April and August.

Pentatoma ligata Stal. Kansas, Douglas county; April and October. New to Kansas.

Mormidea lugens Fab. Kansas, Douglas county; June; July, twilight.

Œbalus pugnax Fab. Kansas, Sedgwick county; September, in pear orchard. Douglas county; November.

Euschistus tristigmus Say. Kansas, Douglas county; April; July, twilight (taken with variety).
tristigmus Say, var. pyrrhocerus H.-Schf. Kansas, Douglas county; July; July, twilight; August. New to Kansas.
variolarius Pal. de Beauv. Kansas, Douglas county; May; May, at electric light; July; August; October; October, at night.

Hymenarcys æqualis Say. Kansas, Douglas county; September, October.
nervosa Say. Kansas, Douglas county; July.

(Subfamils *Pentatominæ.*)

Menecles insertus Say. Kansas, Douglas county; April, November. New to Kansas.

Thyanta custator Fab. Kansas, Sedgwick county; May, in timber along Arkansas river; August, on farm. Douglas county; June; August, twilight.—Colorado, Garden of the Gods; July. Colorado Springs; August (31).

perditor Fab. Kansas, Douglas county; September, at electric light on river bridge.

Nezara hilaris Say. Kansas, Douglas county; June, at night.

(Subfamily *Asopinæ.*)

Podisus maculiventris Say (=spinosus Dallas). Kansas, Douglas county; March; May; July; July, twilight; August; November.

Family COREIDÆ.

Corynocoris distinctus Dallas. Kansas, Douglas county; June.

Archimerus calcarator Fab. Kansas, Douglas county; June; June, twilight. New to Kansas.

Acanthocephala instabilis Uhl. Kansas, Douglas county; October. New to Kansas.

terminalis Dallas. Kansas, Douglas county; June, October. New to Kansas.

Leptoglossus oppositus Say. Kansas, Douglas county; October; October, twilight; November; November, twilight. New to Kansas.

Chariesterus antennator Fab. Kansas, Sedgwick county; August.

Catorhintha mendica Stal. Kansas, Douglas county; July; July, twilight; November.—Colorado, Colorado Springs; August (31).

Anasa armigera Say. Kansas, Douglas county; July, twilight; August; October.

tristis De G. Kansas, Douglas county; April to November.

Protenor belfragei Hagl. Colorado, Manitou; July.

Megalotomus (Alydus) quinquespinosus Say. Colorado, Colorado Springs; August.

Alydus eurinus Say. Kansas, Douglas county; August. New to Kansas.

pilosulus H.-Schf. Kansas, Douglas county; August. New to Kansas.

pluto Uhl. Colorado, Colorado Springs; August.

Harmostes fraterculus Say. Kansas, Douglas county; August. New to Kansas.

reflexulus Stal. Kansas, Douglas county; May, at night.—Colorado, Colorado Springs; August (31).

Corizus hyalinus Fab. Colorado, Colorado Springs; August (31).

lateralis Say. Kansas, Douglas county; September.—Colorado, Colorado Springs; July.

nigristernum Sign. Kansas, Douglas county; May, July. New to Kansas.

sidæ Fab. Kansas, Douglas county; August, on cockle-bur blossoms. New to Kansas.

Serinetha trivittata Say. Kansas, Douglas county; April, on daffodils in bloom; October, all stages; November, all stages; noxious in entering houses in search of winter quarters.

Family Berytidæ.

Jalysus spinosus Say. Kansas, Douglas county; June; June, twilight; July; August; October.—Colorado, Colorado Springs; July, August. Cheyenne canyon, July (31).

Family Lygæidæ.

Oncopeltus fasciatus Dallas. Kansas, Douglas county; October.

Lygæus reclivatus Say. Kansas, Douglas county; May.—Colorado, Colorado Springs; August (31).

Nysius angustatus Uhl. Colorado, Garden of the Gods; July. Green Mountain Falls; July. Bear Creek canyon; July (31). Colorado Springs; August.

minutus Uhl. Kansas, Douglas county; July; August; August, at night. Sedgwick county; September. New to Kansas.—Colorado, Colorado Springs; August. Tabernash, August.

Belonochilus numenius Say. Kansas, Douglas county; November. New to Kansas.

Ischnorhynchus resedæ Panz. Colorado, Cheyenne canyon; July. Manitou; July (31, =didymus Zett.) Colorado Springs; August.

Ischnodemus falicus Say. Kansas, Douglas county; May.

Blissus leucopterus Say. Kansas, Douglas county; April; July; September, at electric light.

Geocoris ater Fab. (=uliginosus Say, erroneously fuliginosus). Kansas, Douglas county; April.

pallens Stal. Colorado, Colorado Springs; August.

Phlegyas annulicrus Stal. Kansas, Douglas county; May, at night. New to Kansas.

Œdancala dorsilinea Am. et Serv. (=dorsalis Say). Kansas, Douglas county; July.

Chiroleptes serripes Ol. Kansas, Douglas county; May; June, at electric light; July, at electric light; August, at electric light; December.

Orthæa (Pamera) basalis Dallas. Kansas, Douglas county; May, at night; September, at electric light.

The name of this species is omitted in Lethierry and Severin's catalogue, and the generic name has been changed by Mr. G. W. Kirkaldy.

Cnemodus mavortius Say. Kansas, Douglas county; July, at electric light.

Sphragisticus nebulosus Fal. Kansas, Douglas county; August, at night. New to Kansas.—Colorado, Manitou; July. Colorado Springs; August (erroneously accredited "Manitou Park," 31, =Trapezonotus).

Cryphula parallelogramma Stal. Kansas, Douglas county; June, twilight.

Eremocoris ferus Say. Kansas, Douglas county; August, October. New to Kansas.

Family Pyrrhocoridæ.

Largus cinctus H.-Schf. Colorado, Cheyenne canyon; August (31).

Family Tingidæ.

Piesma cinerea Say. Kansas, Douglas county; May, July, August.—Colorado, Colorado Springs; August (31).

Corythuca ciliata Say. Colorado, Green Mountain Falls; July.

fuscigera Stal. Colorado, Colorado Springs; August.

pergandei Heid. Kansas, Douglas county; May, at night (metatype); October. New to Kansas.

Family PHYMATIDÆ.

Phymata erosa Linne. Kansas, Douglas county; July, found clinging on back of drone-fly, *Eristalis tenax* Linne, which it had evidently captured; September.—Colorado, Colorado Springs; August (31, = fasciata Gray).

Family ARADIDÆ.

Aradus quadrilineatus Say. Kansas, Douglas county; May. New to Kansas.

Family REDUVIDÆ.

Oncerotrachelus acuminatus Say. Kansas, Douglas county; May. New to Kansas.

Pygolampis pectoralis Say. Kansas, Douglas county; June, at electric light; July, at electric light. New to Kansas.

Stenopoda culiciformis Fab. Kansas, Douglas county; July, at street lamp. New to Kansas.

Reduvius personatus Linne. Kansas, Douglas county; May, at night; June, at night; July; August. New to Kansas.

Melanolestes picipes H.-Schf. Kansas, Douglas county; April, frequent in house at night in lighted rooms; May; May, at electric light and at night.

Zelus luridus Stal. Colorado, Cheyenne canyon; July.

Acholla multispinosa De G. Kansas, Douglas county; July; July, twilight; August; September; October. New to Kansas.

Sinea diadema Fab. Kansas, Douglas county; September.

raptoria Stal. Kansas, Douglas county; June. New to Kansas.

Reduviolus ferus Linne. Kansas, Douglas county; April; June; June, twilight, at electric light and at night; July; November.—Colorado, Green Mountain Falls; July. Colorado Springs; July; August (31, =Coriscus).

pallescens Reut. Kansas, Douglas county; May, at night. New to Kansas.

rufusculus Reut. Colorado, Colorado Springs; August.

Family ANTHOCORIDÆ.

Anthocoris musculus Say. Colorado, Colorado Springs; August.

Triphleps insidiosus Say. Kansas, Douglas county; June; June, twilight; July; August.

Family CAPSIDÆ (MIRIDÆ).

(In this family Mr. Otto Heidemann has kindly arranged the names of the genera and species according to the latest systems of classification as advocated by Prof. O. M. Reuter in his work, "Hemipterologische Speculationen, Die Classification der Capsiden," 1905: Festschrift für Palmen No. 1; and also by Mr. G. W. Kirkaldy in "List of the Genera of the Pagiopodous Hemiptera-Heteroptera," 1906: Trans. Am. Ent. Soc., vol. XXXII, pp. 117–156. "In doing so," Mr. Heidemann writes, "I followed Professor Reuter in his phylogenetic arrangement of his divisions, but use the word "tribe" as a more appropriate term, and which is generally adopted now by the American systematists. I do not agree with Mr. Kirkaldy in his sweeping changes of nomenclature, which he proposes in some of his papers. I have retained the names of divisions or tribes in accordance with Professor Reuter's statements in his last work on the classification of the Capsidæ.")

(Tribe *Plagiognathini.*)

Sthenarus rubidus Uhl. Colorado, Colorado Springs; August (type, 31).

Reuteroscopus (Episcopus) ornatus Reut. Kansas, Douglas county; July, at night; August; September. Sedgwick county; September.—Colorado, Colorado Springs; August.

Psallus delicatus Uhl. Kansas, Douglas county; May. New to Kansas.

Plagiognathus obscurus Uhl. Kansas, Douglas county; August; August, at night; September.

politus Uhl. Kansas, Douglas county; June; June, twilight; July, at night; September. New to Kansas.

annulatus Uhl. Kansas, Douglas county; May; June, twilight; August. New to Kansas.

Chlamydatus (Agalliastes) associatus Uhl. Colorado, Colorado Springs; July, August. Garden of the Gods; July (31). Denver; August.

(Tribe *Oncotylini.*)

Megalocoleus (Macrocoleus) coagulatus Uhl. Colorado, Green Mountain Falls; July. Garden of the Gods; July. Colorado Springs; August. Cheyenne canyon; July. Manitou; July.

Oncotylus sericatus Uhl. Colorado, Colorado Springs; July. Green Mountain Falls; July (cotypes, 31).

(Tribe *Cyllocorini.*)

Orthotylus flavosparsus Sahl. Kansas, Douglas county; July, August. New to Kansas.

diaphanus Kirsch. The identification was made by Mr. Heidemann as "probably" this species. Kansas, Douglas county; June, twilight. New to Kansas.

Orthotylus translucens, new species. Colorado, Cheyenne canyon, near Colorado Springs; July, 1894.

Elongate; minutely pubescent, more apparent on wing-covers than on body; legs and antennæ as well as the body uniform straw-yellow, probably grass-green when fresh, same as thickened portions of wings, which are mainly that color. Head rounded, smooth; eyes very prominent, black, somewhat deep-set above and below, narrowing the vertex, which has a faint triangular depression with the base formed against a narrow transverse ridge on posterior margin of the head. Tylus short and narrow, defined at base by a deep incisure between antennal insertions; rostrum slender, reaching well between the middle coxæ, black at extreme tip. First joint of antennæ somewhat stout, about as long as the vertical diameter of an eye; second joint slender and nearly four times as long as the first; others missing.

The pronotum widens obliquely backward, the posterior margin having nearly twice the expanse of the anterior which is about equal to the length, all margins straight; the anterior lobes are slightly rounded, the posterior ones curved and reflexed. Surface smooth and convex; a deep, narrow incision extends entirely across transversely just in front of the middle, at the center of which is a deep notch that separates two apparently large tumid callosities; collum compressed in front. Scutellum equal in length and breadth, smoothly convex, but divided into two unequal parts, the smaller basal portion being defined by an incision extending across and curving into the anterior angles.

(Tribe *Cyllocorini.*

Orthotylus translucens—*continued.*

Wings extend beyond the abdomen nearly half their length; unless faded, the thickened parts are translucent green, perhaps yellowish along costa, and all the veins are suffused with the general color; membranes are clear hyaline.

Abdomen somewhat elongate, less than half as wide as the thorax. The last joint of each tarsus, including the claw, is infuscated.

Length to tip of wings, 4.5 mm., to end of abdomen, 2.75 mm.; width of thorax, 1.25 mm. Described from a single male specimen collected by the author.

Mr. Otto Heidemann considers this specimen "near *prasinus* Fallen." The description of *O. viridicatus* Uhl. agrees very closely, the most notable distinction being black membranes of that species.

This specimen has remained so long unnamed, and, as authorities generally hesitate to describe and name a species from only one specimen, at least without retaining the specimen for type, I have taken the work on myself in naming and describing it, mainly to avoid listing a species as unknown. The type belongs to the collection of the University of Kansas. For the Colorado list.

METATYPES.—Four female specimens, collected by F. Rogers, Kansas City, Mo., May 13 and 20, on trunks of locust trees. In collection of University of Kansas. Those with complete antennæ have the joints proportioned as follows: First and second joints as described for type; third and fourth together a little longer than the second, slender, appearing slightly infuscated in certain lights. The head appears wider between the eyes than with the type, and the eyes above and below are not as deep-set; the rostrum fails to reach the middle coxæ; the abdomen is as wide as the thorax, and the wing membranes are very slightly dusky, but far from being black in any sense.

Ceratocapsus (Melinna) fasciatus Uhl. Kansas, Douglas county; August; August, at twilight. New to Kansas.

(Melinna) lutescens Reut. Kansas, Douglas county; August. New to Kansas.

Ilnacora (subgenus Corinala) stallii Reut. Kansas, Douglas county; May, June, August, September. New to Kansas.

(Sthenarops) chloris Uhl. Kansas, Sedgwick county; June. New to Kansas.

(Sthenarops) malina Uhl. Kansas, Douglas county; June. New to Kansas.

Malacocoris irroratus Say. Kansas, Douglas county; July.

Diaphnidia debilis Uhl. Colorado, Cheyenne canyon; July. Colorado Springs; August (metatypes, 31).

(Tribe *Dicyphini.*)

Hyaliodes vitripennis Say. Kansas, Douglas county; July.

Dicyphus californicus Stal. Colorado, Colorado Springs; August.

(Tribe *Labopini.*)

Lopidea confluens Say. Colorado, Colorado Springs; July, August. New to the Colorado list.

media Say. Kansas, Douglas county; June; June, twilight; July.

(Tribe *Cyllocorini.*)

Oncerometopus nigriclavus Reut. Colorado, Colorado Springs; either July or August (31); taken again in August of 1906.

Hadronema militaris Uhl. Colorado, Colorado Springs; August. Garden of the Gods; July (31).

picta Uhl. Colorado, Colorado Springs; July (types, 31).

Halticus uhleri Giard. Kansas, Douglas county; June, twilight; July, at night; July; August.

bractatus Say. Colorado, Colorado Springs; August. Bear Creek canyon; July.

Strongylocoris (Stiphrosoma) stygicus Say. Kansas, Sedgwick county; June. Douglas county; June; June, twilight and at night.

(Stiphrosoma) croceipes Uhl. Colorado, Colorado Sprıngs; July, August.

(Stiphrosoma) robustus Uhl. Colorado, Tabernash; August

(Tribe *Capsini.*)

Lygus pratensis Linne. Kansas, Douglas county; March, April; June, twilight; August; September. Sedgwick county; April.—Colorado, Manitou; July. Green Mountain Falls; July. Colorado Springs; July; August (31).

distantii Atk. (= scutellatus Distant). Kansas, Douglas county; May, immature; July. New to Kansas.—Colorado, Colorado Springs; July; August. Green Mountain Falls; July. Denver; August. New to the Colorado list.

guttatipes Uhl. Colorado, Manitou; August (types, 31).

invitus Say, dark variety. Kansas, Douglas county; June. New to Kansas.

monachus Uhl., var. Kansas, Douglas county; May, June. New to Kansas.

plagiatus Uhl. Kansas, Douglas county; April. New to Kansas.

(Hadrodema) pulverulenta Uhl. Kansas, Douglas county; June, July, November.

Pœciloscytus basalis Reut. Kansas, Douglas county; June, July.—Colorado, Colorado Springs; August (31).

Pœcilocapsus lineatus Fab. Kansas, Douglas county; June.

Polymerus (Systratiotus) venaticus Uhl. Kansas, Douglas county; June; June, twilight.

(Systratiotus) americanus Reut., variety. Kansas, Douglas county; May.

Camptobrochis nebulosus Uhl. Kansas, Douglas county; June; July; July, twilight. Colorado, Manitou; July. Cheyenne canyon; July. Colorado Springs; August.

grandis Uhl. Kansas, Douglas county; June, twilight.

Calocoris rapidus Say. Kansas, Sedgwick county; August. Douglas county; June; June, at electric light.

superbus Uhl. Colorado, Colorado Springs; August.

Phytocoris eximius Reut. Colorado, Tabernash; August. New to the Colorado list.

interspersus Uhl. Colorado, Cheyenne canyon; July (type, 31).

(Tribe *Capsini.*)

Neurocolpus nubilus Say. Kansas, Douglas county; August. Colorado, Garden of the Gods; July. Colorado Springs; July (31).

Miridius, not recognizable. Kansas, Douglas county; August, at night. New to Kansas.

(Tribe *Garganini.*)

Garganus fusiformis Say. Kansas, Douglas county; August, twilight; September, at electric light. Fort Leavenworth; September.

(Tribe *Mirini.*)

Stenodema (Miris) instabilis Uhl. (= affinis Reut.) Kansas, Douglas county; April, June. New to Kansas.

Trigonotylus pulcher Reut. Colorado, Colorado Springs; July, August.

Miris (Leptoterna) amœna Uhl. Colorado, Manitou; July.

Callimiris tarsalis Reut. Kansas, Douglas county; July; August, at electric light. New to Kansas.

Family CLINOCORIDÆ.

Clinocoris lectularius Linne. Kansas, Douglas and Sedgwick counties.—Colorado, Colorado Springs; August (31, =Acanthia).

Family ACANTHIIDÆ.

Acanthia pallipes Fab. Colorado, Colorado Springs; July (31, =Salda).

Family GELASTOCORIDÆ (NERTHRIDÆ).

Gelastocoris sp. Colorado, Colorado Springs; August.

This specimen had been regarded as *oculatus* Fabricius, until it was examined by Mr. J. R. de la Torre Bueno, who wrote: "It is something different. Just what it is I do not care to pronounce upon. Your insect comes in a group of apparently undescribed forms from the Pacific coast." And later he added: "I believe it has at times been confused with *variegatus* Guerin."

Family BELOSTOMATIDÆ.

Benacus haldemanum (Leidy), Stal. (=grisea Say). Kansas, Douglas county; May, at electric light; July, at electric light. New to Kansas list.

Amorgius uhleri Mont. Kansas, Douglas county; July, at electric light.

The specimens of this species were formerly classified as *americanum* Leidy, but on being submitted to Mr. J. R. de la Torre Bueno, the determination was corrected. New to Kansas list.

Belostoma flumineum Say. Kansas, Douglas county; June.

Family CORIXIDÆ.

(A few representatives of this family are awaiting determination. Scarcely any authorities are able to distinguish the species.)

Corixa alternata Say. Kansas, Douglas county; June and July, all at electric light.

tumida Uhl. Colorado, Colorado Springs; August (31).

Family GERRIDÆ.

Gerris marginata Say. Kansas, Douglas county; April.
remigis Say. Colorado, Colorado Springs; August. Manitou; August.

SUMMARY OF FAMILIES AND SPECIES, INCLUDING NAMED VARIETIES.

Pentatomidæ	22	Anthocoridæ	2
Coreidæ	21	Capsidæ (Miridæ)	55
Berytidæ	1	Clinocoridæ	1
Lygæidæ	18	Acanthiidæ	1
Pyrrhocoridæ	1	Gelastocoridæ (Nerthridæ)	1
Tingidæ	4	Belostomatidæ	3
Phymatidæ	1	Corixidæ	2
Aradidæ	1	Gerridæ	2
Reduvidæ	12		

Total, 148.

LIST OF HEMIPTERA-HOMOPTERA.

The explanations given at the beginning of the list of the Heteroptera are also applicable to the Homoptera here listed. The valuable work of Professors Gillette and Baker on the Hemiptera of Colorado is indicative of what possibilities await similar investigation within the confines of Kansas.

Although the whole time I have spent in collecting insects in Colorado would hardly be worth consideration, my list herewith, however, refers to forty-seven species found in that state compared with ninety-eight species taken in Kansas, but in this count sixteen species were collected in both states. In the Colorado bulletin, the number of species of Homoptera credited in any way to me as the collector is twenty-eight, while the lack of such acknowledgment in regard to one other species seems accountable to an oversight. Three species and three varieties of my Colorado additions are not recorded in the bulletin. Of those that are, or should be, acknowledged in the bulletin, six species of jassids were described as new; one cercopid was described as a new species, though it is now regarded as a variety; and one fulgorid was mentioned as a new species but not described. All these make a total of seven new species and one new variety of my collecting in Colorado. There are forty-one species new to the Kansas list.

For assistance in the determination of numerous species, most of which were new to the University collection, acknowledgments are due to Prof. E. D. Ball, especially for work on the Jassidæ, excepting, however, the Typhlocybinæ, which received the attention of Prof. C. P. Gillette. Mr. E. A. Schwarz kindly identified some psyllids, and Mr. Otto Heidemann has also aided me. Mr. E. P. Van Duzee very kindly reviewed my preliminary list, making some changes and other corrections which were of material help.

Names of species in all the families are arranged alphabetically when more than one occurs in a genus.

Family CICADIDÆ.

Cicada dorsata Say. Kansas, Sedgwick county; August. Douglas county, August, September.

tibicen Linne. Kansas, Sedgwick county; August. Douglas county; July; August; September; October, first week. New to the Kansas list.

Family MEMBRACIDÆ.

(Arrangement of genera after Mr. F. W. Goding's "Bibliographical and Synonymical Catalogue of the Described Membracidæ of North America," published in Bull. Ill. St. Lab. Nat. His., vol. III.)

Entylia sinuata Fab., var. bactriana Germar. Kansas, Douglas county; May; June, twilight. New variety to the Kansas list.

Publilia concava Say. Kansas, Douglas county; May.

modesta Uhl. Colorado, Colorado Springs; August (31).

Ceresa bubalus Fab. Kansas, Douglas county; August.—Colorado, Colorado Springs; August (31); variety, Buffalo, August.

diceros Say. Kansas, Douglas county; July.—Colorado, Colorado Springs; August (31).

taurina Fitch. Kansas, Douglas county; June, July. New to Kansas.

Stictocephala festina Say. Kansas, Sedgwick county; June.

inermis Fab. Kansas, Douglas county; August. New to Kansas.

Telamona ampelopsidis Harr. Kansas, Douglas county; June; June, twilight. New to Kansas.

pyramidata Uhl. Colorado, Colorado Springs; July, August.

Acutalis calva Say. Kansas, Douglas county; June. New to Kansas.

Cyrtolobus vau Say. Colorado, Garden of the Gods; July. Green Mountain Falls; July (31).

Enchenopa binotata Say. Kansas, Douglas county; June; June, twilight.

Campylenchia curvata Fab. Colorado, Colorado Springs; August (31).

Family FULGORIDÆ.

(Arrangement of genera after Mr. O. H. Swezey, in his preliminary catalogue of the Fulgoridæ, Bulletin No. 3, Ohio Dept. Agric.)

Ormenis pruinosa Say. Kansas, Douglas county; July; July, twilight.

Amphiscepa bivittata Say. Kansas, Sedgwick county; August. Douglas county; August.

Bruchomorpha pallidipes Stal. Colorado, Colorado Springs; August (31).

Phylloscelis atra Germar, var. Kansas, Douglas county; August.

Dictyophara microrhina Wlk. Kansas, Sedgwick county; August.

Scolops grossus Uhl. Kansas, Douglas county; July. New to Kansas.

spurcus Uhl. Kansas, Douglas county; July, August.

sulcipes Say. Kansas, Douglas county; July, August.—Colorado, Colorado Springs; July, August (31).

Amalopota fitchi Van D. Kansas, Douglas county; July, at night; August, at night. New to Kansas.

Anotia kirkaldyi Ball. Kansas, Douglas county; August, at night. New to Kansas.

Family FULGORIDÆ.

Cixius stigmatus Say. Kansas, Sedgwick county; August. Douglas county; July; July, twilight; August.—Colorado, Colorado Springs; August (31).

Myndus, n. sp. Colorado, Manitou; July (31).

This was likely *impiger*, since described by Prof. E. D. Ball, who agrees in this opinion.

Oliarus complectus Ball. Kansas, Douglas county; June, twilight. New to Kansas.

Kelisia crocea Van D. Kansas, Douglas county; August, at night.

Pissonotus pallipes Van D. Colorado, Colorado Springs; August.

Stobæra tricarinata Say. Kansas, Douglas county; April; June; July, at night; August; August, at night.

Liburnia lututenta Van D. Kansas, Douglas county, April. New to Kansas.

ornata Stal. Kansas, Douglas county; July, twilight; August, twilight. New to Kansas.

osborni? Van D. Colorado, Colorado Springs; April. August, macropterous form. New to the Colorado list.

Family CERCOPIDÆ.

Clastoptera obtusa Say. Kansas, Douglas county; June; June, twilight.

obtusa Say, var. osborni G. & B. Colorado, Cheyenne canyon; July. Manitou; August (31).

Family JASSIDÆ.

(Arrangement of genera after Mr. E. P. Van Duzee's Catalogue of Jassoidea, Trans. Amer. Ent. Soc., vol. XXI, with the adoption of recent generic names and other changes as far as known.)

(Subfamily *Bythoscopinæ.*)

Bythoscopus distinctus Van D. Kansas, Douglas county; June, twilight.

Pediopsis erythrocephala G. & B. Colorado, Colorado Springs; August (31, type).

viridis Fitch. Colorado, Colorado Springs; August (31).

Idiocerus moniliferæ O. & B. Kansas, Douglas county; June. New to Kansas.

nervatus Van D. Kansas, Douglas county; April. New to Kansas.

perplexus G. & B. Colorado, Cheyenne canyon; July. Colorado Springs; August (31, types). Also taken again at the latter place, August, 1906.

rufus G. & B. Colorado, Colorado Springs, August (31, cotypes).

snowi G. & B. Kansas, Douglas county; June, at electric light. New to Kansas.—Colorado, Colorado Springs; August (description in 31, but credit omitted, types). Buffalo; August, 1906.

suturalis Fitch. Kansas, Douglas county; June, at electric light. New to Kansas.—Colorado, Manitou; July (31).

(Subfamily *Bythoscopinæ.*)

Agallia constricta Van D. Kansas, Douglas county; April; June, twilight; July; July, twilight; August. New to Kansas.
novella Say. Kansas, Douglas county; June, twilight; July, August.
quadripunctata Prov. Kansas, Douglas county; May, June.
sanguinolenta Prov. Kansas, Douglas county; April, August.—Colorado, Colorado Springs; August (31). Denver; August.
uhleri Van D. Colorado, Bear Creek canyon; July. Colorado Springs; July, August.

(Subfamily *Tettigoninæ.*)

Oncometopia costalis Fab. Colorado, Colorado Springs; April, July, August.
Tettigonia bifida Say. Kansas, Douglas county; June, twilight; September.
hieroglyphica Say. Typical. Kansas, Douglas county; April, September.
hieroglyphica Say, var. dolobrata Ball. Kansas, Douglas county; June. New to Kansas.
hieroglyphica Say, var. uhleri Ball. Colorado, Cheyenne canyon; July. Colorado Springs; August. New variety to the Colorado list.
Diedrocephala coccinea For. Kansas, Douglas county; May; June; June, twilight; August; September, at night.
Dræculacephala angulifera Wlk. Kansas, Sedgwick county; June. New to Kansas.
mollipes Say. Kansas, Douglas county; May, at night; June; June, twilight; July; July, at electric light; August, at lamplight; September; September, at night.
Helochara communis Fitch. Colorado, Colorado Springs; August (31). Tabernash; August.
Xerophlœa peltata Uhl. Kansas, Sedgwick county; September.
Gypona dorsalis Spangb. Kansas, Douglas county; August.

The single specimen, which had been held in doubt for some time, was again submitted to Mr. E. P. Van Duzee, who reported as follows: "The *Gypona* you send I still consider very near to *dorsalis* of Spangburg, if not a pale form of that species. I have Kansas specimens so labeled in my own collection. It is closely allied to both *melanota* and *mexicana* of Spangburg, and even more closely to *bipunctata* Spangburg, from which it hardly differs except by its broader form and the different position of the ocelli." New to Kansas.

Gypona octolineata Say. Kansas, Douglas county; March, September.
octolineata Say, var. flavilineata Fitch. Kansas, Douglas county; June; June, at night; July, at electric light and at night; September, at electric light and at night. New to Kansas.—Colorado, Colorado Springs; August.

(Subfamily *Jassinæ.*)

Xestocephalus pulicarius Van D. Kansas, Douglas county; August.
Paramesus (Allygus) coloradensis G. & B. Colorado, Colorado Springs; August.
twiningi Uhl. Kansas, Douglas county; September, at night. New to Kansas.—Colorado, Colorado Springs; August.

(Subfamily *Jassinæ.*)

Platymetopius acutus Say. Kansas, Douglas county; October. New to Kansas.

frontalis Van D. Kansas, Sedgwick county; September. Douglas county; June; July, at night.

Deltocephalus flavocostatus Van D. Kansas, Douglas county; May, at night. June, twilight; July; August; September.

inimicus Say. Kansas, Douglas county; June; June, twilight; July; August; September, at night.

nigrifrons Forbes. Kansas, Douglas county; April; May; May, twilight; July; August. New to Kansas.

melscheimeri Fitch. Kansas, Douglas county; May, at night; June, sweepings; July.—Colorado, Colorado Springs; August.

signatifrons Van D. Colorado, Denver; August. Colorado Springs; August.

sylvestris O. & B. Kansas, Douglas county; May, July. New to Kansas.

weedi Van D. Kansas, Douglas county; June, twilight; August. New to Kansas.

Athysanus (Limotettix) exitiosa Uhl. Kansas, Sedgwick county; September, in vineyard. Douglas county; May, July; September, at night; October 2, very numerous in lawn grass between walks and gutter of street on campus of University of Kansas.—Colorado, Colorado Springs; August (31).

Eutettix incerta G. & B. Colorado, Manitou; July (31, type).

manitou Ball. Colorado, Colorado Springs; August. New to the Colorado list.

seminuda Say. Kansas, Sedgwick county; September, swept from foliage of peach trees. Douglas county; August, at lamplight.

(Phlepsius) strobi Fitch. Kansas, Sedgwick county; September. Douglas county; July, at night; August, at night.

Phlepsius irroratus Say. Kansas, Sedgwick county; June; September. Douglas county; May; June; June, twilight; July; August; August, at electric light; September; September, at night.

decorus O. & B. Kansas, Douglas county; July, September. New to Kansas.

ovatus Van D. Colorado, Colorado Springs; August,

Scaphoideus immistus Say. Kansas, Douglas county; June; June, at electric light and at night; July.

scalaris Van D. Kansas, Douglas county; July. New to Kansas.

Thamnotettix clitellaria Say. Kansas, Douglas county; June.

longula G. & B. Kansas, Douglas county; April. New to Kansas.

fitchi Van D. Kansas, Douglas county; July. New to Kansas.

heidemanni Ball. Colorado, Tabernash; August. New to Colorado list.

Chlorotettix galbanata Van D. Kansas, Douglas county; July.

spatulata O. & B. Kansas, Douglas county; June.

unicolor Fitch. Colorado, Colorado Springs; August.

(Subfamily *Jassinæ.*)

Jassus olitorius Say (= Cœlidia subbifasciata Say). Kansas, Douglas county; July, August, September, October.

Gnathodus abdominalis Van D. Kansas, Sedgwick county; September, in pear orchard. Douglas county; September, at electric light.— Colorado, Garden of the Gods; July. Green Mountain Falls; July. Colorado Springs; August (31). Buffalo; August.

impictus Van D. Kansas, Douglas county; June. New to Kansas.

manitou G. & B. Colorado, Manitou; July (31, type).

Cicadula sex-notata Fal. Kansas, Douglas county; July, August.— Colorado, Green Mountain Falls; July. Colorado Springs; July, August (31, = divisa Uhler). Denver; August.

variata Fal. Kansas, Douglas county; August.

(Subfamily *Typhlocybinæ.*)

Empoasca albolinea Gill. Kansas, Douglas county; July, at electric light; September, at electric light. New to Kansas.

mali Le B. Kansas, Douglas county; July, August.

obtusa Walsh. Kansas, Sedgwick county; September, sweepings in slough-grass among timber bordering Arkansas river. Douglas county, August.— Colorado, Cheyenne canyon; July. Manitou; July. Colorado Springs; August (31).

smaragdula Fal. Colorado, Cheyenne canyon; July. Colorado Springs; August (31).

viridescens Walsh. Kansas, Douglas county; May; June, twilight; July, August. New to Kansas.

Dicraneura abnormis Walsh. Kansas, Douglas county; April; April, at night; May; May, at night; July; August, "pale" form.

fieberi Loew. Kansas, Douglas county; May, at night; July. New to Kansas.

Typhlocyba comes Say. Typical. Kansas, Douglas county; April; April, on currant and gooseberry bushes; May; July; November.

comes Say, var. basilaris Say. Kansas, Douglas county; April, on currant and gooseberry bushes; July, August.

comes Say, var. coloradensis Gill. Kansas, Sedgwick county; September, on fruit farm.— Colorado, Denver; August. New variety to the Colorado list.

comes Say, var. maculata Gill. Kansas, Douglas county; July; aberrant form with black scutellum, April.

comes Say, var. scutelleris Gill. Kansas, Douglas county; April.

comes Say, var. vitis Harr. Kansas, Douglas county; July, August.

comes Say, var. ziczac Walsh. Colorado, Denver; August. New variety to the Colorado list.

obliqua Say. Kansas, Douglas county; March; April, both bright and smoky colored, on currant and gooseberry bushes; June, twilight, with pale yellow lines wanting on head.

obliqua Say, var. nœvus Gill. Kansas, Douglas county; aberration with pale yellow lines instead of red; June, twilight.

(Subfamily *Typhlocybinæ.*)

Typhlocyba rosæ Harr. Kansas, Douglas county; May, at lamplight; July; August. New to Kansas.—Colorado, Colorado Springs; July, August. Garden of the Gods; July. Cheyenne canyon; July (31).

tricincta Fitch. Kansas, Douglas county; July, August.

trifasciata Say. Kansas, Douglas county; August.

vulnerata Fitch. Kansas, Sedgwick county; September, on fruit farm. Douglas county; July, August, October.

Family PSYLLIDÆ.

Aphalara angustipennis Riley. Colorado, Green Mountain Falls; July.

calthæ Linne. Colorado, Green Mountain Falls; July. Colorado Springs; July (31).

polygoni Föerst. Kansas, Douglas county; September. New to Kansas.

utahensis Riley. Colorado, Green Mountain Falls; July (31).

Psylla coryli Riley. Colorado, Manitou; July (31).

Pachypsylla celtidis-asteriscus Riley. Kansas, Douglas county; April. New to Kansas.

celtidis-mamma Riley. Kansas, Douglas county; adults in March, April, and October; galls on leaves of hackberry throughout the season. New to Kansas.

celtidis-minuta Riley. Kansas, Sedgwick county; April, on farm near Wichita. New to Kansas.

Family APHIDIDÆ.

(Mr. C. E. Sanborn has worked up the species which he was able to find in the state and published the results under the title of "Kansas Aphididæ," in University Science Bulletin, volume III, Nos. 1 and 8. However, I am able to record the following two species whose names are not entered on the separate Kansas list. The determinations were made by Mr. Sanborn.)

Schizoneura americana Riley. Kansas, Douglas county; August.

In the twilight of the evening I took several winged specimens. The air had floating in it numerous white insects. After capturing some I noticed it was a cottony secretion which gave them their white appearance and also sustained them or caused them to be wafted along by the wind. They appeared to be leaving elm trees after a shower of rain. New to Kansas list.

Lachnus longistigma Monell. Kansas, Douglas county; May, November; taken while flying. New to Kansas list.

SUMMARY OF FAMILIES AND SPECIES, INCLUDING VARIETIES.

Cicadidæ	2	Jassidæ	82
Membracidæ	14	Psyllidæ	8
Fulgoridæ	19	Aphididæ	2
Cercopidæ	2		

Total, 129.

LIST OF ORTHOPTERA AND EUPLEXOPTERA.

Previous explanations in regard to the circumstances under which my collecting was done hold true in respect to the insects of the above-named orders, whose names and records are here presented. The arrangement used follows that of Dr. S. H. Scudder in his catalogue of 1899, except that the family Forficulidæ is separately considered as constituting the order Euplexoptera, which is therefore placed in position after the Orthoptera, according to Prof. V. L. Kellogg's method, instead of before, as was formerly done. Recent changes in nomenclature are adopted so far as known.

Considerable progress has already been made towards a knowledge of the orthopteran species occurring in Kansas, principally through the efforts of Mr. F. B. Isely, who gives the names of ninety-seven species, including the one species of Forficulidæ, which should be separately considered, in his paper entitled "Notes on Kansas Orthoptera." This paper was published in Transactions of the Kansas Academy of Science, volume XIX, pages 238–249. Another paper deserving of mention, "The Melanopli of Kansas," was prepared jointly by Prof. S. J. Hunter and Mr. W. S. Sutton, and it appeared in different issues of *Psyche*, volume IX. A compilation of the names and records of the species mentioned in these articles, together with those that are reported as being found in Kansas according to Scudder's catalogue and other miscellaneous sources of information, and the addition of what can be found by inspection of all named specimens in different departments of the University, would afford a nearly complete list for the state. Such help as my list offers in this direction is freely granted to whoever undertakes the work as suggested.

In all, my list gives the names of seventy species and one variety, besides one species of Euplexoptera, which were taken in Kansas. Twenty-six species are not reported in Isely's list. The Colorado collecting includes thirty-one species, eight of which are new to the list published by Prof.

C. P. Gillette, in Bulletin No. 94, Colorado Agricultural Experiment Station. Six species were found in both states.

Quite a number of my specimens were identified by Mr. James A. G. Rehn, together with other unnamed material belonging to the University collections, which were sent to him for study by Dr. F. H. Snow, and Mr. Rehn's interesting and valuable report under the title of "Notes and Descriptions of Orthoptera from the Western United States in the Entomological Collection of the University of Kansas," was published in Transactions of the Kansas Academy of Science, volume XIX. Both Mr. A. N. Caudell and Prof. Lawrence Bruner have answered promptly and courteously my inquiries concerning specimens submitted. References are given in their proper places, calling attention to Scudder's authentic types as mentioned in his "Revision of the Orthopteran Group Melanopli," in Proceedings United States National Museum, volume 20.

Family BLATTIDÆ.

Ischnoptera bolliana Sauss.-Zehnt. Kansas, Douglas county; June, at night and at electric light; July. Not reported in Isely's list.

Ischnoptera sp.? Kansas; March and April, under stones and rubbish; September, at random; September, with oöthecæ, from combs in a beehive badly ravaged by wax-worms (*Galleria mellionella* Linne).

Could not be determined definitely from immature female specimens whether *pennsylanica* De G. or *couloniana* Sauss. However, as Mr. Isely records *pennsylvanica* in his list as occurring in beehives, perhaps the preference should be given this name, although *couloniana* was found in Texas. An adult male of *pennsylvanica* is one of a very few specimens saved from a collection begun in boyhood days while living in Oil City, Venango county, Pennsylvania.

Ischnoptera uhleriana Sauss. Kansas, Douglas county; June; June, at electric light. Not reported in Isely's list.

Blatta germanica Linne. Kansas, Douglas and Sedgwick counties.—Colorado, Colorado Springs. Pueblo. Denver.

A nymph collected in Lawrence, August twilight, was traveling through grass in dooryard, which fact indicates that the species migrates on foot. It is a pest common all through the year in households, restaurants, and bakeries.

Themnopteryx deropeltiformis Brunn. Kansas, Douglas county; January, in house; March; April; June, at night. Not reported in Isely's list.

Stylopyga orientalis Linne. Kansas, Douglas county; June, in cupboard of kitchen; July; August; September, under electric street light; Decemcember 4, dead, but fresh specimen.

Family MANTIDÆ.

Stagmomantis carolina Linne. Kansas, Douglas county; September; October, at electric light. Sedgwick county; September.

Family PHASMIDÆ.

Diapheromera femorata Say. Kansas, Douglas county; September. Sedgwick county; August.

Family ACRIDIIDÆ.

(Subfamily *Tettiginæ.*)

Tettix hancocki Morse. Kansas, Douglas county; May.

obscurus Hanck. Kansas, Douglas county; April, August, September, October.

Paratettix cucullatus Morse. Kansas, Douglas county; June, September, October.

toltecus Sauss. Kansas, Douglas county; May. Not reported in Isely's list.

Tettigidea lateralis Say. Kansas, Douglas county; April. Not reported in Isely's list.

(Subfamily *Tryxalinæ.*)

Syrbula admirabilis Uhl. Kansas, Douglas county; August, at electric light; September. Sedgwick county; August.

Opeia obscura Thom. Colorado, Colorado Springs; August. New to Colorado list.

Cordillacris (Alpha) occipitalis Thom. Colorado, Colorado Springs; August.

Phlibrostroma quadrimaculatum Thom. Colorado, Garden of the Gods; July. Colorado Springs; August. Buffalo, August.

Orphulella pelidna Burm. Kansas, Douglas county; September. Not reported in Isely's list.

speciosa Scudd. Kansas, Douglas county; August, at electric light; September.

Dichromorpha viridis Scudd. Kansas, Douglas county; July.

Ageneotettix scudderi Brun. Colorado, Colorado Springs; August.

Aulocara elliotti Thom. Colorado, Colorado Springs; August.

(Subfamily *Œdipodinæ.*)

Arphia arcta Scudd. Colorado, Colorado Springs; April. New to Colorado list.

carinata Scudd. Kansas, Douglas county; August, at electric light. Sedgwick county; August. Not reported in Isely's list.

conspersa Scudd. Kansas, Douglas county; data lost. Not reported in Isely's list.

infernalis Sauss. Kansas, Douglas county; April. Not reported in Isely's list.

tenebrosa Scudd. Colorado, Colorado Springs; August.

Chortophaga virdifasciata De G. Kansas, Douglas county; April, May, June, September. Sedgwick county; August.—Colorado, Colorado Springs; April.

Encoptolophus sordidus Burm. Kansas, Douglas county; September.

(Subfamily *Œdipodinæ.*)

Hippiscus rugosus Scudd. Kansas, Douglas county; August, at electric light; September. Sedgwick county; August; August, at electric light.

tuberculatus Pal. de Beauv. Kansas, Douglas county; May.

neglectus Thom. Colorado; Colorado Springs; April. Manitou; August.

Dissosteira carolina Linne. Kansas, Douglas county; July to October. Sedgwick county, August.

longipennis Thom. Kansas, Sedgwick county; August; August, at electric light. Not reported in Isely's list.—Colorado, Colorado Springs; July 21, 1898, great invasion on the streets after dark, attracted by electric lights (see account in Trans. Kan. Acad. Sci., vol. XX, p. 112); and collected in August.

Spharagemon æquale Say. Colorado, Colorado Springs; August.

collare Scudd. Colorado, Colorado Springs; August.

Derotmema haydeni Thom. Colorado, Colorado Springs; August.

Mestobregma kiowa Thom. Colorado, Garden of the Gods; July. Colorado Springs; August. Denver; August.

Matator pardalinus Sauss. Colorado, Colorado Springs; August.

Trimerotropis citrina Scudd., var. isabelline McNeill. Kansas, Douglas county; June, at electric light. Variety not reported in Isely's list.

fratercula McNeill. Colorado, Garden of the Gods; July. Manitou; July. New to Colorado list.

laticincta Sauss. Colorado, Colorado Springs; August. New to Colorado list.

melanoptera McNeill. Colorado, Colorado Springs; August. New to Colorado list.

monticola Sauss. Colorado, Colorado Springs; August.

præclara McNeill. Colorado, Colorado Springs; August. New to Colorado list.

Circotettix undulatus Thom. Colorado, Green Mountain Falls; July.

Hadrotettix trifasciatus Say. Colorado, Colorado Springs; August. Denver; August.

(Subfamily *Acridiinæ.*)

Schistocerca alutacea Harr. Kansas, Sedgwick county; August.

americana Drury. Kansas, Douglas county; September, October. Sedgwick county; August.

Campylacantha acutipennis Scudd. Kansas, Douglas county; October. Not reported in Isely's list.

olivacea Scudd. Kansas, Douglas county; September, October.

Hesperotettix pratensis Scudd. Kansas, Sedgwick county; August.

Melanoplus bivittatus Say. Kansas, Douglas county; July to September. Sedgwick county; August.—Colorado, Colorado Springs; August (Scudder's type, Revision of Melanopli).

coccineipes Scudd. Colorado, Colorado Springs; August (Scudder's type, Revision of Melanopli).

conspersus Scudd. Colorado, Colorado Springs; August.

(Subfamily *Acridiinæ.*)

Melanoplus differentialis Uhl. Kansas, Douglas county; July to October. Sedgwick county; August.

femur-rubrum De G. Kansas, Douglas county; August, September.

flabellifer Scudd. Colorado, Colorado Springs; August (Scudder's type, Revision of Melanopli).

flavidus Scudd. Colorado, Colorado Springs; August (Scudder's type, Revision of Melanopli).

packardii Scudd. Kansas, Sedgwick county; August.—Colorado, Colorado Springs; July, August. Garden of the Gods; July (Scudder's types, Revision of Melanopli).

plumbeus Dodge. Colorado, Colorado Springs; August (Scudder's type, Revision of Melanopli). New to Colorado list.

scudderi Uhl. Kansas, Douglas county; September.

Family LOCUSTIDÆ.

Scudderia furcata Brun. Kansas, Douglas county; September; September, at night; October. Sedgwick county; August.

Amblycorypha scudderi Brun. Kansas, Douglas county; July. Not recorded in Isely's list.

Microcentrum laurifolium Linne. Kansas, Douglas county; August, September, October.

Cyrtophyllus perspicillatus Linne. Kansas, Douglas county; August, at night, captured by aid of light of lantern high up in elm tree (see Trans. Kan. Acad. Sci., vol. XX, p. 111). Not recorded in Isely's list.

Conocephalus crepitans Scudd. Kansas, Douglas county; September; September, at electric light. Sedgwick county; August. Also brown variety, Sedgwick county; August; August, at electric light.

nebrascensis Brun. Kansas, Douglas county; August, at electric light.

triops Linne. Kansas, Douglas county; September, at electric light. Not recorded in Isely's list.

Orchelimum glaberrimum Burm. Kansas, Douglas county; August, at electric light; September; October.

longipenne Scudd. Kansas, Douglas county; July, at electric light.

nigripes Scudd. Kansas, Douglas county; August, September, October.

volantum McNeill. Kansas, Douglas county; July, at electric light. Not recorded in Isely's list.

Xiphidium attenuatum Scudd. Kansas, Douglas county; August, at electric light.

brevipenne Scudd. Kansas, Douglas county; September. Not recorded in Isely's list.

fasciatum De G. Kansas, Douglas county; July and August, both at electric light.—Colorado, Colorado Springs; August. New to Colorado list.

nemorale Scudd. Kansas, Douglas county; October.

Family LOCUSTIDÆ.

Ceuthophilus bruneri Scudd. Kansas, Douglas county; June (nymph). Sedgwick county; data lost. Not recorded in Isely's list.

inquinatus Scudd. Kansas, Douglas county; September. Not recorded in Isely's list.

tuckeri Rehn. New species, to be described. Kansas, Douglas county; October, at night. Addition to Kansas list.

Udeopsylla nigra Scudd. Kansas, Douglas county; June, at night.

robusta Hald. Kansas, Sedgwick county; on farm, data lost. Not recorded in Isely's list.

Family GRYLLIDÆ.

Gryllotalpa borealis Burm. Kansas, Douglas county; July, at electric light.

Tridactylus apicalis Say. Kansas, Douglas county; May, along sandy banks of Kansas river. Not recorded in Isely's list.

Ellipes minuta Scudd. Kansas, Douglas county; May, along sandy banks of Kansas river. Not recorded in Isely's list.

Nemobius fasciatus De G. Kansas, Douglas county; July and August, both at electric light. Sedgwick county; August, at electric light.

fasciatus De G., var. vittatus Harr. Kansas, Douglas county; September, October.

Gryllus abbreviatus Aud.-Serv. Kansas, Douglas county; September, October. Sedgwick county; August.

luctuosus Aud.-Serv. Kansas, Douglas county; June and July, all at electric light. Not recorded in Isely's list.

pennsylvanicus Burm. Kansas, Douglas county; July; July, at electric light.

Œcanthus angustipennis Fitch. Kansas, Douglas county; September.

fasciatus Fitch. Kansas, Douglas county; September.

niveus De G. Kansas, Sedgwick county; August.

quadripunctatus Beut. Kansas, Douglas county; June, twilight; September, in company with *fasciatus* Fitch. Sedgwick county; August.

Xabea bipunctata De G. Kansas, Douglas county; August, at electric light. Not recorded in Isely's list.

Hapithes agitator Uhl. Kansas, Douglas county; August, colony on ailanthus bush. Not recorded in Isely's list.

SUMMARY OF FAMILIES AND SPECIES, INCLUDING VARIETIES.

Blattidæ	6	Acridiidæ	54
Mantidæ	1	Locustidæ	20
Phasmidæ	1	Gryllidæ	14

Total, 96.

ORDER *EUPLEXOPTERA*.

Family FORFICULIDÆ.

Labia minor Linne. Kansas, Douglas county; July, at night; August, twilight and at night; October.

LIST OF NEUROPTEROUS INSECTS.

No further explanations are necessary regarding the collecting than have been previously stated. The arrangement used here follows the catalogue of Mr. Nathan Banks, in Transactions of the American Entomological Society, volume XIX, mainly in the disposition of the generic and specific names, although the rank of the orders as advocated by Prof. V. L. Kellogg, in his "American Insects," is maintained.

With one exception, in the case of the Psocidæ, as referred to in the proper place, no attempt has been made hitherto towards publishing a list of the neuropterous insects found in Kansas. Consequently, if the present list of those possessing Kansas records be duly considered as forming a preliminary state list, a beginning is made with fifty-eight species and one variety. The same rule, if not presuming too much, may also apply to the Colorado examples, since I am not aware that any list has been published for that state; therefore, the names of thirty-one species here presented form a beginning. Six species were found in both states.

The determinations of the University material, including most of my collections, have been made by Mr. Nathan Banks, excepting a number of examples in the order Odonata which received the attention of Mr. E B. Williamson. A few speci mens of May-flies and stone-flies which had not been fully identified were submitted to Prof. James G. Needham, for study. He was unable to give specific names for the greater number as some were in bad condition and some undescribed. However, his valuable remarks concerning each form are quoted, since all knowledge gained will help in the end towards defining each species when more material shall be available.

ORDER *EPHEMERIDA*.

Family EPHEMERIDÆ.

(All of the Douglas county, Kansas, specimens were collected at electric light on or near bridge across the Kansas river, at Lawrence, except in one instance, which is denoted.)

Polymitarchys albus Say. Kansas, Douglas county; July and August. (See notes on collecting, Trans. Kan. Acad. Sci., vol. XX, p. 116.)

Family EPHEMERIDÆ.

Hexagenia bilineata Say. Kansas, Douglas county; July and September.

venusta Eaton. Kansas, Douglas county; July and August.

Pentagenia quadripunctata Walsh. Kansas, Douglas county; June, July, and August.

Siphlurus sp. Kansas, Douglas county; June and July.

The results of Professor Needham's study of this species is stated by him as follows: "Probably new; one male subimago, one male imago lacking setæ, and two female subimagos badly broken; with all these, owing to their condition, there is barely sufficient material for description. I have made a photograph of the female subimago which is in best condition, but I have not taken your leave to retain a specimen, for it is still too inadequately represented in your own collection." The male imago was taken in July, in daytime, at a distance of more than a mile from the river.

Siphlurus sp. Colorado, Cheyenne canyon, near Colorado Springs; July.

Professor Needham reported on it as follows: "Probably new; one broken female. It is different from the foregoing, and appears to be different from all described species. I have specimens from New Mexico received years ago; I am holding them, waiting for the arrival of an adult male, for description. It only contributes to the existing confusion to describe May-flies from females alone, or to describe them without giving a figure of the female appendages."

Heptagenia pulchella Walsh. Kansas, Douglas county; June and July.

Heptagenia sp. Colorado, Buffalo, Platte canyon; August.

Professor Needham says of this: "A single male which I cannot identify; may be undescribed, but I cannot be sure. In order to be certain in identification of May-flies, and of some stone-flies also, I require to have sufficient material so that I can make slide mounts of the male appendages, and I prefer to have alcoholic material sent me."

Rithogenia elegantula Eaton. Kansas, Douglas county; July.

Leptophlebia sp. Colorado, Tabernash; August.

Nothing further than the genus could be learned, as Professor Needham explains: "This specimen came badly broken." Male.

Callibætis eatoni Needh. Colorado, Tabernash; August. Colorado Springs; August.

Regarding the specimens thus designated, Professor Needham wrote: "Sp. nov. of Eaton's monograph, p. 195. It is well described there, but not named; it is new, in my opinion. I have been calling the species *C. eatoni* in my own collection. Three male imagos and one female subimago; the latter I have photographed."

Callibætis sp. Colorado, Colorado Springs; July and August.

Professor Needham regards it as follows: "Male. I doubt if it be *coloradensis* Banks; but since the male is undescribed, it is impossible to say. I have not the female of that species in my collection; the size of this male and the black spots on the costa seem hardly to be expected in conjunction with a female of the character described by Banks."

Cænis diminuta Wlk. Kansas, Douglas county; July to September. (See notes on collecting, Trans. Kan. Acad. Sci., vol. XX, p. 116.)

ORDER *PLECOPTERA*.

Family PERLIDÆ.

(With few exceptions, which are denoted in each case, the Douglas county, Kansas, specimens were collected at electric light on bridge across the Kansas river at Lawrence.)

Acroneuria ruralis Hagen. Kansas, Douglas county; July.

Perla ephyre Newm. Kansas, Douglas county; July, at electric light in town, away from river; August, found resting in daytime.

flavescens Walsh. Kansas, Douglas county; last week of June, at electric light one mile from river; July, found resting in daytime, and July, at electric light on bridge.

lurida Hagen. Kansas, Douglas county; July.

xanthenes Newm. Kansas, Douglas county; July, at electric light in town; August, at electric light on bridge.

Perlinella placida Hagen. Kansas, Douglas county; July.

Perlinella, species probably new. Kansas, Douglas county; August, found resting in daytime more than a mile from the river.

In his report on this, Professor Needham says: "I agree it is a new species, but it is not in fit condition for description; the ventral lamina of the female is important above most characters, and it is not visible in this specimen."

Pseudoperla occipitalis Pict. Kansas, Douglas county; July.

Chloroperla bilineata Say. Kansas, Douglas county; May.

Alloperla imbecilla Say (also determined as pallidula Banks). Colorado, Cheyenne canyon, near Colorado Springs; July. Also swept from bushes at edge of stream in Stratton park, below entrance to Cheyenne canyon; August.

Capnia pygmæa Burm. (Specimen badly damaged, but evidently this species.) Kansas, Douglas county; April, on bank of Kansas river.

ORDER *ODONATA*.

(The arrangement advanced by Mr. E. B. Williamson in "The Dragonflies of Indiana," Twenty-fourth Annual Report of the Department of Geology and Natural Resources of Indiana, is here adopted so far as is therein denoted for this order.)

Family CALOPTERYGIDÆ.

Calopteryx maculata Pal. de Beauv. Kansas, Douglas county; June, twilight, a wanderer on University hill, evidently settling down to pass the night.

Hetærina basalis Hagen. Kansas, Douglas county; August, at Wakarusa river.

Family AGRIONIDÆ.

Lestes forcipatus Ramb. Kansas, Douglas county; May, at night.

rectangularis Say. Kansas, Douglas county; August.

unguiculatus Hagen. Kansas; June, in timber along Kansas river; August, in town.

Argia agrioides Calv. Colorado, Colorado Springs; July, 5915 feet; August.

Family AGRIONIDÆ.

Amphiagrion saucium Burm. Colorado, Colorado Springs; July and August.

Enallagma civile Hagen. Kansas, Douglas county; June, near Kansas river. Colorado, Colorado Springs; July and August.

clausum Morse. Colorado, Colorado Springs; August.

prævarum Hagen. Colorado, Colorado Springs; July and August.

Ischnura perparva McL. Colorado, Colorado Springs; July.

verticalis Say. Kansas, Douglas county; May, skirting river; June, near river.

Family GOMPHIDÆ.

Herpetogomphus designatus Selys. Kansas, Douglas county; July, in town.

Gomphus amnicola Walsh. Kansas, Douglas county; June, near river.

Ophiogomphus severus Hagen. Colorado, Buffalo, Platte canyon; August.

Family ÆSCHNIDÆ.

Æschna multicolor Hagen. Colorado, Colorado Springs; August.

Anax junius Drury. Kansas, Douglas county; May, near river; May 26, in town; August 11, inside of window.

Family LIBELLULIDÆ.

Perithemis domitia Drury. Kansas, Douglas county; July, along river.

Celithemis eponina Drury. Kansas, Douglas county; July, along river.

Sympetrum corruptum Hagen. Kansas, Douglas county; October, in town.—Colorado, Colorado Springs and Denver; August.

rubicundulum Say. Kansas, Douglas county; September, in town.

rubicundulum Say, var. assimilatum Uhl. Kansas, Douglas county; September, in town.

semicinctum Say. Colorado, Colorado Springs; August.

vicinum Hagen. Kansas, Douglas county; July.

Pachydiplax longipennis Burm. Kansas, Douglas county; September, in town.

ORDER *ISOPTERA*.

Family TERMITIDÆ.

Termes flavipes Koll. Kansas, Douglas county; July, from rotten oak stringers in sidewalk.

lucifugus Rossi. Colorado, Colorado Springs; August.

ORDER *CORRODENTIA*.

(Prof. V. L. Kellogg treats of the family Psocidæ before Atropidæ, contrary to the arrangement of Mr. Nathan Banks.)

In the Transactions of the Kansas Academy of Science, volume XIX, Mr. F. F. Crevecœur refers to four species of psocids in his additions to the list of Kansas Hemiptera, but my species is not mentioned there.

Family PSOCIDÆ.

Pterodela pedicularia Linne. Kansas, Douglas county; September.

Family ATROPIDÆ.

Atrops divinatoria Fab. Kansas, Douglas county; September, found on boards used for spreading wings of Lepidoptera; October, from leaf of book; November, among fragments of insects.

ORDER *NEUROPTERA*.

(Attention hardly needs to be called to the wide separation of the neuropterous insects having active metamorphosis from those with complete metamorphosis, between which the orders Orthoptera, Euplexoptera, Hemiptera and Thysanoptera are now interposed according to rank.)

Family SIALIDÆ.

Chauliodes rasticornis Ramb. Kansas, Douglas county; May, at electric light near river.

Corydalis cornuta Linne. Kansas, Douglas county; July and August, all at electric light, usually near river. Larvæ in riffles of Wakarusa river; July.

A single larva was once found under electric light on Kansas river bridge, where it had evidently crawled from the water, and in doing so necessarily climbed a high pier.

Family CHRYSOPIDÆ.

Chrysopa majuscula Banks. Colorado, Denver; August.

nigricornis Burm. Kansas, Douglas county; April, at electric light; June; October.—Colorado, Colorado Springs and Denver; August.

oculata Say. Kansas, Douglas county; May; June, twilight; July; July, twilight, Sedgwick county; August.—Colorado, Denver; August.

plorabunda Fitch. Kansas, Douglas county; April; June; July, at night; August; August, at night; November. Sedgwick county; August. Colorado, Cheyenne canyon and Garden of the Gods; July. Colorado Springs; August.

rufilabris Burm. Kansas, Douglas county; July, twilight; August, at night. Colorado, Colorado Springs; August.

sabulosa Banks. Colorado, Denver; August.

Family HEMEROBIDÆ.

Hemerobius stigmaterus Fitch. Kansas, Douglas county; April; May; May, at night; August, at night; September, at night, and October.

Sympherobius amiculus Fitch. Kansas, Douglas county; June.

perparvus McL. Kansas, Douglas county; April, at lamplight.

Micromus variolomus Hagen. Colorado, Denver and Tabernash; August.

Family MYRMELEONIDÆ.

Brachynemurus abdominalis Say. Kansas, Douglas county; August; August, at night. Sedgwick county; August.

hubbardi Cur. Colorado, Garden of the Gods; July.

nigrilabris Hagen. Colorado, Colorado Springs; August.

Family CONIOPTERYGIDÆ.

Coniopteryx vicina Hagen. Kansas, Douglas county; May.

ORDER *MECOPTERA*.

Family PANORPIDÆ.

Bittacus stigmaterus Say. Kansas, Douglas county; July, at night; August, in weeds of thicket.

strigosus Hagen. Kansas, Douglas county; June, in thicket of timber along Kansas river; July, in weeds of thicket.

ORDER *TRICHOPTERA*.

(Night after night, as the weather permitted, almost regularly during three collecting seasons and at odd times since, I have visited the electric lights on the bridge crossing the Kansas river at Lawrence, particularly in search of different kinds of caddis-flies, which were attracted there at times in great numbers, and my success in collecting them is attested by as complete a representation of species for this locality as could be possible, perhaps.)

Family LIMNEPHILIDÆ.

Limnephilus oslari Banks. Colorado, Tabernash; August.

Dicosmœcus atripes Hagen. Colorado, Tolland, on train; August.

Apatania pallida? Hagen. Kansas, Douglas county; October, attracted by lamplight in room.

Family LEPTOCERIDÆ.

Leptocerus dilutus Hagen. Kansas, Douglas county; July to October, all at electric light on river bridge.

Setodes albida Wlk. Kansas, Douglas county; July to September, all at electric light on river bridge.

uwarowii Koll. Kansas, Douglas county; July to September, all at electric light on river bridge.

Mystacides punctata Banks. Kansas, Douglas county; July to September, all at electric light on river bridge. (Type, August; others, homotopotypes.)

Olemira americana Banks. Colorado, Manitou; July.

Family HYDROPSYCHIDÆ.

Hydropsyche cockerelli Banks. Colorado, Buffalo; August.

kansensis Banks. Kansas, Douglas county; June to September, all at electric light on river bridge. (Type wanting; specimens on hand, homo-topotypes. See notes on collecting, Trans. Kan. Acad. Sci., vol. XX, p. 117.)

Family Hydrcpsychidæ.

Hydropsyche phalerata Hagen. Kansas, Douglas county; May, July, August, and September, all at electric light on river bridge.

scalaris Hagen. Kansas, Douglas county; May, at night; June to October, at electric light on river bridge; April and August, in house at lamplight.

Psychomyia mœsta Banks. Colorado, Buffalo; August, captured as the insects alighted on sides of box cars standing on the bank of Platte creek.

SUMMARY OF FAMILIES AND SPECIES, INCLUDING VARIETIES.

Ephemeridæ	13	Sialidæ	2
Perlidæ	11	Chrysopidæ	6
Calopterygidæ	2	Hemerobidæ	4
Agrionidæ	10	Myrmeleonidæ	3
Gomphidæ	3	Coniopterygidæ	1
Æschnidæ	2	Panorpidæ	2
Libellulidæ	8	Limnephilidæ	3
Termitidæ	2	Leptoceridæ	5
Psocidæ	1	Hydropsychidæ	5
Atropidæ	1		

Total, 84.

LIST OF DIPTERA.

My opening remarks, together with the introduction to the list of Hemiptera-Heteroptera, relate the circumstances under which my collecting was done. A statement is also made that all my specimens, whenever desirable, have been freely added to the entomological collections of the University of Kansas.

Unless otherwise stated in the proper places, the arrangement and nomenclature used in the preparation of this list of the two-winged flies are adopted in accordance to Prof. J. M. Aldrich's "Catalogue of North American Diptera." The pleasure I had in association with Professor Aldrich a number of years ago, when he spent some time in research study at the University of Kansas, induces me to express my high estimation of his very helpful work as shown by this catalogue. His recent assistance so promptly rendered in the determination of some of my specimens belonging to the family Dolichopodidæ is hereby gratefully acknowledged.

To Mr. D. W. Coquillett, through the courtesy of Dr. L. O. Howard, of the Bureau of Entomology, United States Department of Agriculture, Washington, D. C., I am deeply indebted for very valuable and generous services which he has repeatedly afforded me in the identification of specimens. Other acknowledgments are accredited in the proper places to specialists who have rendered assistance in naming specimens belonging to certain families. Nearly all the specimens of my early collecting were worked over almost in turn by Dr. S. W. Williston, Mr. W. A. Snow, Prof. J. M. Aldrich, and more recently by Dr. C. F. Adams, during the course of their research studies at the University of Kansas. The determinations made by myself have depended largely upon comparisons of my examples with named specimens in the University collection.

As shown by the tabulated summary at the end of the list, nearly half of the species taken by me in Kansas are new to the state lists, the preliminary one being published by Dr.

F. H. Snow in the Kansas University Science Bulletin, volume II, No. 5, to which additions were made by Mr. F. F. Crevecœur in Transactions of the Kansas Academy of Science, volume XX, pages 90–96. In answer to my inquiry, directed to Prof. T. D. A. Cockerell, whether any list had been attempted for Colorado, I received the reply here quoted: "No list of the Diptera of Colorado has appeared I have a manuscript list, as complete as I have been able to make it, of the Diptera of the Rocky Mountains (principally Colorado and New Mexico), and so can state if any particular species appears to be new to the region." Mr. W. A. Snow published a paper entitled "Diptera of Colorado and New Mexico," in Kansas University Quarterly, volume III, but in this, as well as in a preceding paper, "Notes and Descriptions of Syrphidæ" (*loc. cit.*, vol. I), his references are confined to that one family, the Syrphidæ, and only so far as he had studied the species then represented in the University collections. Thus the names of those species which I have recorded as being found in Colorado should be of material help towards forming a preliminary list for that state.

The finding of new species has been quite gratifying, considering the circumstances and extent of collecting, eleven in all being so far described, in the following families: Mycetophilidæ, three by Adams; Stratiomyidæ, two by Adams; Bombyliidæ, one by Williston; Dolichopodidæ, two by Aldrich; Phoridæ, one by Brues; Syrphidæ, one by Snow; and Borboridæ, one by Adams. All these are designated in the list by the term "type" following the name of each one. Eight species and three varieties are herewith described by me as new, three species and one variety being in the family Bombyliidæ, three species and two varieties in the family Asilidæ, and two species in the family Borboridæ.

Family TIPULIDÆ.

Dicranomyia longipennis Schum. Kansas, Douglas county; May, at night; August. New to the Kansas list.

Helobia hybrida Meigen (=punctipennis Meigen). Kansas, Douglas county; March; April; May, at night (some with mites attached on abdomen); October.—Colorado, Colorado Springs; August.

Gnophomyia tristissima O. S. Kansas, Douglas county; June, twilight.

Pachyrhina ferruginea Fab. Kansas, Douglas county; May, June, August. New to Kansas.—Colorado, Denver; August.

Family PSYCHODIDÆ.

Psychoda alternata Say. Kansas, Douglas county; April; May; June, twilight; August.

Family CHIRONOMIDÆ.

(Due appreciation of the valuable work of Prof. O. A. Johannsen in determining nearly all of the species whose names are listed in this family is hereby gratefully acknowledged. But for his generous services, the midges of Kansas would not be so thoroughly known. The generic names given here are arranged according to the rank given them by Professor Johannsen in New York State Museum Bulletin No. 86.)

Ccratopogon albarius Coq. Kansas, Douglas county; July, at electric light.

bipunctatus Linne. Kansas, Douglas county; May, in window; June, twilight; August. Sedgwick county, April. New to the Kansas list.—Colorado, Colorado Springs, August. (Not listed in Aldrich's catalogue, but mentioned in N. Y. State Mus. Bull. No. 86, p. 100. Very similar if not identical with *squamipes*, determined by himself.)

pergandei Coq. Kansas, Sedgwick county; April.

pilosulus Coq. Kansas, Douglas county; September, at electric light. New to Kansas.

specularis Coq. Kansas, Douglas county; May. New to Kansas.

squamipes Coq. (See remark about *bipunctatus* Linne.) Kansas, Douglas county; April, at night; May, in windows of house in early morning; May, at night; June; June, at night; July; August; September. New to Kansas.

subasper Coq. Kansas, Douglas county; June, July.—Colorado, Colorado Springs; August.

variipennis Coq. Kansas, Douglas county; May, at night.

Ablabesmyia (Tanypus) carnea Fab., var. *b* Joh. Kansas, Douglas county; April. New to Kansas. (Not listed in Aldrich's catalogue, but references are given in N. Y. State Mus. Bull. No. 86, p. 140.)

monilis Linne. Kansas, Douglas county; April. New to Kansas.

nigropunctata Staeg. Kansas, Douglas county; June; June at night; July. New to Kansas. (Not listed in Aldrich's catalogue, but references are given in N. Y. State Mus. Bull. No. 86, p. 155.)

Tanypus stellatus Coq. Kansas, Douglas county; September, at electric light. New to Kansas.

Chironomus albipennis Meigen. Kansas, Douglas county; July, at electric light. New to Kansas. "Defective specimen, but resembles *albipennis*," is the remark by Professor Johannsen. (Not listed in Aldrich's catalogue, but references are given in N. Y. State Mus. Bull. No. 86, p. 223.)

attenuatus Wlk. Kansas, Douglas county; June; July, at electric light; August. New to Kansas.

decorus Joh. (N. Y. State Mus. Bull. 86, p. 39.) Kansas, Douglas county; May, June; July, at electric light; September, at electric light. New to Kansas.

Family CHIRONOMIDÆ.

Chironomus flavus Joh. (N. Y. State Mus. Bull. 86, p. 225.) Kansas, Douglas county; July, at electric light; August; September, at electric light. New to Kansas.

frequens Joh. (N. Y. State Mus. Bull. 86, p. 230.) Kansas, Douglas county; July and August, all at electric light. New to Kansas.

fulviventris Joh. (N. Y. State Mus. Bull. 86, p. 229.) Kansas, Douglas county; July, at electric light. New to Kansas.

fulvus Joh. (N. Y. State Mus. Bull. 86, p. 224.) Kansas, Douglas county; June, at electric light. New to Kansas.

fumidus Joh. (N. Y. State Mus. Bull. 86, p. 221.) Kansas, Douglas county; July, at electric light. New to Kansas.

halteralis Coq., var. Kansas, Douglas county; July, at electric light. New to Kansas.

hyperboreus Staeg. Colorado, Colorado Springs; April.

lineatus Say. Kansas, Douglas county; July, at electric light. New to Kansas.

modestus Say. Kansas, Douglas county; June. New to Kansas.

nigricans Joh. (N. Y. State Mus. Bull. 86, p. 219.) Kansas, Douglas county; July, at electric light. New to Kansas.

pallidus Joh. (N. Y. State Mus. Bull. 86, p. 230.) Kansas, Douglas county; June, twilight; July, at electric light. New to Kansas. "Resembles *pallidus*," is the *dictum* of Professor Johannsen.

riparius Meigen. Kansas, Douglas county; March, April. New to Kansas.

scalænus Schrank, var. Kansas, Douglas county; June, twilight. New to Kansas.

similis Joh. (N. Y. State Mus. Bull. 86, p. 236.) Kansas, Douglas county; May; May, twilight; June, at night; September, in window. New to Kansas.

stigmaterus Say. Kansas, Douglas county; July and September, all at electric light. New to Kansas.

tentans Fab. Colorado, Colorado Springs; August.

Cricotopus sylvestris Fab. Kansas, Douglas county; April. New to Kansas.

trifasciatus Panz. Kansas, Douglas county; September, at electric light. New to Kansas. (Not listed in Aldrich's catalogue but references are given in N. Y. State Mus. Bull. 86, p. 253.)

Comptocladius byssinus Schrank. Kansas, Douglas county; April, May. Sedgwick county; April. New to Kansas.—Colorado, Colorado Springs; April. Tabernash; August.

Orthocladius nivoriundus Fitch. Kansas, Douglas county; May. (Unfortunately the only specimen was lost from mount in transit.) New to Kansas.

politus Coq. Kansas, Douglas county; July, at electric light. New to Kansas.—Colorado, Colorado Springs; April, July, August.

Tanytarsus nigripilus Joh. (N. Y. State Mus. Bull. 86, p. 287.) Kansas, Douglas county; March; April, at night. New to Kansas.

Family CULICIDÆ.

Anopheles maculipennis Meigen. Kansas, Douglas county; August.

punctipennis Say. Kansas, Douglas county; April, in window of house; August; August, twilight; December.

Janthinosoma musica Say. Kansas, Douglas county; June, July.

Psorophora ciliata Fab. Kansas, Douglas county; September, at night.

Culex consobrinus Desv. Kansas, Douglas county; March, at night; April; May, twilight; June; October (most abundant in this month); October, at night in house; November (all determined by Dr. E. P. Felt). On Kansas list as *inornatus* Will.

impiger Wlk. Kansas, Douglas county; May, at night; July; July, twilight (all determined by Dr. E. P. Felt, who considers specimens by this name as distinct from *nigripes* Zett.) New to Kansas list.

inornatus Will. Kansas, Douglas county; March; April; May, at night (determined by Dr. C. F. Adams). Similar specimens were identified as *consobrinus* Desv. by Dr. E. P. Felt. However, Doctor Williston has declared that his species cannot possibly be *consobrinus*.

pipiens Linne. Kansas, Douglas county; May; June; June, twilight; August; November (all known in collection as *fatigans* Wied.); June, twilight, and July, twilight (determined by Dr. H. G. Dyar). New to the Kansas list.—Colorado, Denver; August (determined by Dr. H. G. Dyar).

restuans Theob. Kansas, Douglas county; May; May, twilight; June; June, twilight; July, twilight; August; August, twilight; September, in house; October (all determined by Dr. E. P. Felt). New to the Kansas list.

sylvestris Theob. Kansas, Douglas county; April; May, at night and in house; June; June, twilight; July; July, twilight; August; October. New to Kansas.—Colorado, Denver; August (determined by Dr. H. G. Dyar).

tarsalis Coq. Kansas, Douglas county; April; June, twilight; August, October, November (all determined by Dr. E. P. Felt); June, twilight (determined by Dr. H. G. Dyar); also, July, twilight (compared).—Colorado, Denver and Colorado Springs; August (determined by Dr. H. G. Dyar).

triseriatus Say. Kansas, Douglas county; May (bred in University museum from foul water in pail containing bones placed there to soak; determined by Dr. L. O. Howard); June; June, twilight; July, twilight; August.

Tæniorhynchus perturbans Wlk. Kansas, Douglas county; August, twilight. New to Kansas.

Aëdes (Culex) abfitchii Felt.? Colorado, Tabernash; August (determined by Dr. H. G. Dyar, from a single badly rubbed specimen).

Sayomyia punctipennis Say. Kansas, Douglas county; July, at electric light (determined by O. A. Johannsen); August, at night (determined by Dr. E. P. Felt). New to Kansas.

Family MYCETOPHILIDÆ.

Ceroplatus apicalis Adams. Kansas, Douglas county; August (type).
terminalis Coq. (Jour. N. Y. Ent. Soc., 1905, p. 69.) Kansas, Douglas county; July, September. New to Kansas.

Sciophila nigricauda Adams. Colorado, Bear Creek canyon, near Colorado City; July (type).

Neoglaphyroptera bivittata Say. Kansas, Douglas county; August; August, twilight; October.
cuneola Adams. Colorado, Colorado Springs; August (type).
oblectabilis Loew. Kansas, Douglas county; July, twilight; August; September; October.

Mycetophila contigua Wlk. Kansas, Douglas county; March. New to Kansas.
discoidea Say. Kansas, Douglas county; March. New to Kansas.

Zygoneura toxoneura O. S. Kansas, Douglas county; April, August.

Family CECIDOMYIDÆ.

Several specimens, no two alike; cannot be determined for want of their galls.

Family BIBIONIDÆ.

Plecia plagiata Wied. (= heteroptera Say). Kansas, Douglas county; October.

Bibio albipennis Say. Kansas, Douglas county; May, at lamplight.
articulatus Say. Kansas, Douglas county; April, May. New to Kansas.
femoratus Wied. Kansas, Douglas county; April.
pallipes Say. Kansas, Douglas county; April; May, at night. Sedgwick county; April.

Dilophus serotinus Loew. Kansas, Douglas county; October. New to Kansas.

Scatopse atrata Say. Kansas, Douglas county; April. New to Kansas.
notata Linne. Kansas, Douglas county; April, in window; May. New to Kansas.—Colorado, Tabernash; August.
pygmæa Loew. Kansas, Douglas county; April. New to Kansas.

Family RHYPHIDÆ.

Rhyphus alternatus Say. Kansas, Douglas county; April. New to Kansas.
punctatus Fab. Kansas, Douglas county; April; June; June, twilight; July, twilight. New to Kansas.

Family STRATIOMYIDÆ.

Allognosta fuscitarsis Say. Kansas, Douglas county; May, June, July, August. New to Kansas.

Ptecticus trivittatus Say. (=similis Will.) Kansas, Douglas county; June, on heaps of decomposing vegetable and fruit refuse; June; July; August, among vines and weeds and hovering about garbage from house.

Family STRATIOMYIDÆ.

Sargus decorus Say. Kansas, Douglas county; May; May, at night; June; July; September, mostly hovering in shady places or at twilight. —Colorado, Manitou; July.

elegans Loew. Kansas, Douglas county, July. New to Kansas.

viridis Say. Kansas, Douglas county; June. Sedgwick county; April.—Colorado, Colorado Springs; July.

Stratiomyia apicula Loew. Kansas, Douglas county; September.

Euparyphus albipilosus Adams. (Erroneously spelled *albipilus* in Aldrich's catalogue.) Colorado, Colorado Springs; August (type).

mutabilis Adams. Colorado, Colorado Springs; August (type).

Family TABANIDÆ.

Chrysops fulvaster O. S. Colorado, Colorado Springs; July, August.

Tabanus costalis Wied. Kansas, Douglas county; July.

exul O. S. Kansas, Sedgwick county; August.

lineola Fab. Kansas, Douglas county; June, August.

punctifer O. S. Colorado, Colorado Springs; July.

quinquevittatus Wied. Kansas, Douglas county; June. New to Kansas.

sulcifrons Macq. Kansas, Douglas county; July, August, September.

Family LEPTIDÆ.

Xylomyia pallipes Loew. Kansas, Douglas county; May; June; July, twilight.—Colorado, Denver; August.

Chrysopila flavibarbis Adams. Colorado, Colorado Springs; August (compared with types).

humilis Loew. Colorado, Colorado Springs; August.

modesta Loew. Kansas, Douglas county; June; July; July, twilight.

quadrata Say. Kansas, Douglas county; June.

testaceipes Bigot. Colorado, Cheyenne canyon; July. Colorado Springs; August.

Hilarimorpha mikii Will. Colorado, Colorado Springs; July.

Family BOMBYLIIDÆ.

Spogostylum pauper Loew. Kansas, Douglas county; July.

Exoprosopa caliptera Say. Colorado, Buffalo; August.

There is very slight difference only in pattern of wings, and that may be due to variation, between this and *capucina* Fab.

Exoprosopa capucina Fab. Colorado, Buffalo; August.

fasciata Macq. Kansas, Sedgwick county; August. Douglas county; September.

Anthrax alcyon Say (erroneously halcyon). Colorado, Manitou, Colorado Springs, Denver, and Buffalo; August.

Anthrax alta, new species. Colorado, Colorado Springs; August, 1906, one female specimen. Type in collection of the University of Kansas.

Somewhat similar to *inculta* Coq., especially on account of the band of white tomentum on front and margins of thorax, and continuing on across base of scutellum, but differs in the following particulars: To-

Family BOMBYLIIDÆ.

Anthrax alta—*continued.*

mentum of entire front golden yellow, all pile black; face sharply produced below, proboscis lies entirely within the oral cavity, the margins of which are luteous. The eyes, which are emarginate on the posterior sides, are bordered behind with white tomentose, as with *inculta*, back of which is a narrow space covered with dusky tomentose, and this is fringed on posterior margin with short fulvous pile, meeting the long, dense, similarly colored pile on the front of the thorax. Bristles of thorax and scutellum yellow. Fifth and sixth ventral segments of the abdomen are covered with black tomentose, the fifth slightly margined behind with yellow; sparse black pile on all segments of venter similar to that on the dorsal surface.

With reference to the dark areas of the wings, a description of the specimen in this respect is added here. Costal and subcostal cells, the latter as far as tip of costal vein, the marginal for nearly half its length, though faintly at base, and first basal cell clouded with a fuliginous cast extending from base of wing, and which envelops the basal bend of the second vein and the anterior cross-vein. The posterior cross-vein bisects a circular dusky spot and faint dusky spots appear at the base and furcation of the fifth vein, besides a streak which extends along the anterior portion of second basal cell. Halteres yellow with the tip pale, spoon-shaped. Length, 6.5 mm.; wing, 6 mm.

Anthrax alternata Say. Colorado, Denver and Colorado Springs; August.

agrippina O. S. Colorado, Denver; August.

arethusa O. S. Colorado, Manitou; August.

Anthrax comparata, new species. Colorado, Colorado Springs; August, 1894. Two types in the collection of the University of Kansas.

The specimens agree in size and general appearance with *cinefacta* Coq., according to his description of that species, but differ in the following respects: Face wholly black, without any groove in the middle; legs wholly black. Pile of breast and coxæ black, and bristles on middle of posterior margin of scutellum black. Sparse pile on abdomen, at least such as remains on edges, and on the posterior margins of the last three ventral segments, black. Otherwise these ventral segments are black tomentose. Described from specimens which are badly denuded, but still in condition to warrant the establishment of a species.

Anthrax muscaria Coq. Colorado, Denver and Colorado Springs; August.

Anthrax nebulo Coq. Colorado, Denver; August.

Agrees well with description, except that fore tibiæ are not completely destitute of bristles, and size is larger, 12 mm. instead of 9 mm., but being a female specimen, this difference may easily be allowable. In comparison with *ænea* Coq., to which the description refers, the first antennal joint is larger than the second, and the third is conical instead of subglobular at base.

Anthrax sinuosa Wied. Kansas, Douglas county; July.—Colorado, Denver and Colorado Springs; August.

Family BOMBYLIIDÆ.

Anastœchus melanohalteralis, new species. Colorado, Buffalo, Platte canyon; August, 1906; a male and female specimen. Types in the collection of the University of Kansas.

The main reason for establishing this species in comparison with *nitidulus* Fab. (= *barbatus* O. S.), depends on the enlarged black tips of the halteres, which are scoop-shaped or rather obliquely flattened, with edges incurved backward. Stalk of halteres yellow, veins of wings mainly yellow. Aside from the larger size and darker fuliginous wings, the structure and color of the halteres appear of sufficient value to characterize a species distinct from *nitidulus*. Authentic specimens of the latter exhibit yellow halteres with pale knobs, which have an oblique shallow-pitted face directed backwards. Length from front of eyes to tip of abdomen, 8 mm.; wings are slightly longer than body.

Anastœchus melanohalteralis, new species, fulvipennis, new variety. Same locality and date as above; one male specimen. Type in collection of the University of Kansas.

Apparently not different from typical *melanohalteralis* except in larger size and color of wings, which are tinged with brown over half their width anteriorly for two-thirds of their length; apex and posterior margin subhyaline. Length from front of eyes to tip of abdomen, 10 mm.; wing, 11 mm.

Anastœchus nitidulus Fab. Colorado, Colorado Springs; August.

Systœchus candidulus Loew. Kansas, Douglas county; August.

vulgaris Loew. Kansas, Sedgwick county; August.—Colorado, Colorado Springs; August.

Phthiria sulphurea Loew. Colorado, Colorado Springs and Denver; August.

Sparnopolius coloradensis Grote. Colorado, Colorado Springs and Buffalo; August.

fulvus Wied. Kansas, Douglas county; September.

Aphœbantus marcidus Coq. Colorado, Colorado Springs; August.

Desmatomyia anomala Will. Colorado, Garden of the Gods; July (type of genus and species).

Geron senilis Fab. Colorado, Colorado Springs; August.

Family THEREVIDÆ.

Psilocephala hæmorrhoidalis Macq. Kansas, Douglas county; June.

Thereva melanoneura Loew. Kansas, Douglas county; May. New to Kansas.

Family SCENOPINIDÆ.

Scenopinus fenestralis Linne. Kansas, Douglas county; June; July; July, at electric light.

Family MYDAIDÆ.

Mydas clavatus Drury. Kansas, Douglas county; July, flying about and resting on old, rotten apple stump, in bright sunlight in middle of day.

Family ASILIDÆ.

Ospriocerus abdominalis Say. Colorado, Colorado Springs; August.

Scleropogon picticornis Loew. Kansas, Sedgwick county; August. New to Kansas.

Triclis tagax Will. Kansas, Douglas county; June.

Cyrtopogon profusus O. S. Colorado, Manitou; July.

Holopogon phæonotus Loew. Colorado, Green Mountain Falls; July.

Stichopogon trifasciatus Say. Colorado, Colorado Springs; August.

Heteropogon phœnicurus Loew. Kansas, Douglas county; August. New to Kansas.

Deromyia angustipennis Loew. Kansas, Sedgwick county; August, on open prairie.

platyptera Loew. Kansas, Douglas county; July.

ternata Loew. Kansas, Douglas county; July, twilight, flying close under leaves of vines, bushes and weeds of back yards in town; only noticed in the past two years; reported as an enemy of the honey-bee in country. New to Kansas.

winthemi Wied. (= misellus Loew). Kansas, Douglas county; August.

Taracticus octopunctatus Say. Kansas, Douglas county; June.

Cerotainia macrocera Say. Kansas, Douglas county; July. New to Kansas.

Atomosia puella Wied. Colorado, Colorado Springs; July.

Lampria rubriventris Macq. Kansas, Sedgwick county; August.

Protacanthus milbertii Macq. Kansas, Douglas county; August.—Colorado, Colorado Springs; August.

Erax aridus Will. Colorado, Colorado Springs; August.

bastardii Macq. Kansas, Douglas county; July. New to Kansas.

stamineus Will. Colorado, Buffalo; August, including first female specimen for University collection.

Mallophora clausicella Macq., n. var., intermedia. Colorado, Buffalo, Platte canyon; August. Types in collection of the University of Kansas.

The specimens appear to be intermediate forms between *clausicella* Macq. and *megachile* Coq. One specimen has first posterior cell of wing slightly open, but the pile of thorax is black; only one out of three specimens is destitute of black pile on thorax. Length of body ranges from 13 to 15 mm., which measurement is about the same as for *clausicella*, but above that given for *megachile*. The antennal style is as long as with *megachile*.

Promachus vertebratus Say. Kansas, Sedgwick county; August.

Tolmerus annulipes Macq., new variety, delusus. Kansas, Douglas county; June, four females, one male.—Colorado, Colorado Springs; August, one male. Types in the collection of the University of Kansas. New variety for Kansas list.

These specimens merely differ from typical *annulipes* Macq. in the coloration of all the femora, the posterior surface being entirely red, except on the hind pair, where the red is narrowed to a streak.

Tolmerus mesæ, new species. Colorado, Colorado Springs; August, collected on mesa and foot-hills in vicinity of the city. Types: Two males and three females taken in 1894, and one female captured during the summer of 1906, all in the collection of the University of Kansas.

Family ASILIDÆ.

Tolmerus mesæ—*continued.*

Front and face yellowish gray pollinose; gibbosity occupying more than half of the face, clothed with long, pale yellow bristles, the upper part bearing a few short black ones in most cases; all other bristles of front, occiput, and orbits, and hair of cheeks, fore and middle coxæ, pale yellow. Antennæ black, third joint longer than first and second joints together, terminal bristle less than half its length. The first and second antennal joints are clothed with short grayish hair, which is very scanty on the second. Vertex narrow, but little wider than length of first antennal joint, deeply excavated. Dorsum of thorax marked with the two usual median black stripes, very slightly and faintly separated, and two cloudy spots on each side. The dorsum bears strong yellow bristles, laterally and posteriorly; a few on the middle area black. Scutellum with two yellow bristles curved upward and forward from posterior margin. The greater portion of thorax and abdomen is grayish opaque pollinose. Apical margins of abdominal segments are narrowly luteous. Male genitalia prominent, almost straight, if not a little tapering in outline, wholly reddish, together with ventral plates. Oviduct of females piceous, excepting under side of base, which is reddish. Halteres brown.

Femora entirely black; tibiæ and metatarsi red, infuscated towards apices, remaining tarsal joints piceous, excepting basal connections, which are red. Wings hyaline, very faintly clouded on apical portion. Auxiliary and first longitudinal veins entirely, and other veins at base of wing, bright yellow. Greatest length of male, 10 mm.; of female, 12.5 mm.

Tolmerus prairiensis, new species. Kansas, Sedgwick county; August, collected on prairie. Type: One female specimen in collection of the University of Kansas. For the Kansas list.

Front and face bright yellow pollinose, gibbosity occupying more than half of the face, middle part clothed with long yellow bristles, perhaps not more than two black ones, which are quite short, on upper part. Antennæ black excepting extreme apex of second and base of third joints, which portions are tinged with red, first joint clothed with both black and gray hair, second joint with short black hair, third joint a little longer than the first two together, terminal bristle about half as long as the third joint. A short row of white bristles extend upward on each side of front from insertions of antennæ. All bristles on the occiput and orbits, and hairs on the cheeks, fore and middle coxæ, pale yellow. General color of the thorax and abdomen grayish opaque pollinose, the two median black stripes on the dorsum of thorax indistinctly separated, and the two lateral dark spots, one on each side, are somewhat blended into the stripes, probably due largely to discoloration. The dorsum of thorax bears long bristles sparsely placed, yellow on the sides and posterior region, black on the middle area. Scutellum with two yellow bristles curved upward and forward from posterior margin. Apical margin of each abdominal segment reddish to a rather wide extent, oviduct shining piceous tinged with red, its lateral compressions slightly spread apart on under edge.

Family ASILIDÆ.

Tolmerus prairiensis—*continued.*

All femora are black on anterior surface excepting preapical red space, posterior surface red; tibiæ red, infuscated or striped with black on anterior surface, the fore and middle pair being encircled with black at tips; tarsal joints red, infuscated on distal portions, and differs in this respect from *annulipes* Macq. in not being distinctly annulated with black, besides most of the bristles on legs and tarsi are white. Apical portion of wings faintly clouded, including spot in fourth posterior cell. Length, 20 mm.; wing, 10 mm.

Tolmerus prospectus, new species. Colorado, Colorado Springs; August, collected on plains in vicinity of the city. Types: Two male specimens in the collection of the University of Kansas.

Front and face yellowish pollinose, the gibbosity, which occupies more than half of the face, is clothed above with black bristles, below with longer yellow bristles, bordered on each lower side with three black ones of nearly equal length. Antennæ black, the first joint clothed with both yellow and black hair, the second with short, black hair, the third joint being equal in length to the first two together; terminal bristle somewhat shorter than the third joint. Front a little wider above than length of first antennal joint, sunken, bordered on each side just above insertions of antennæ with a short row of pale bristles, beyond which the hair is black, short, and sparse, but distinct on ocellar tubercle. Occipito-orbital bristles wholly pale yellow, joining the long white, silky beard on the cheeks. A long white pubescence covers the fore part of anterior coxæ and fore tips of middle coxæ. General color of thorax and abdomen grayish opaque pollinose; the two black median stripes on dorsum of thorax are faintly separated from each other as well as from the two large dark spots, one on either side. Halteres brown. Dorsum of thorax fringed laterally with long yellow bristles sparsely placed, including a black one on each side; on the posterior middle area there are shorter black bristles; scutellum with two yellow bristles curving upward and forward from posterior margin.

Femora black, with preapical red band; fore and middle tibiæ red, infuscated at middle on front side and black at tip, posterior pair red excepting a black stripe or infuscation along outer surface; tarsal joints reddish and somewhat infuscated. Tips of wings faintly clouded. Genitalia black, with well rounded and slightly curved tips, ventral plates reddish, split with distinct medial and lateral grooves. Length, 13 mm.; wings, 8.5 mm.

In consequence of my study of the series of specimens representing the genus *Tolmerus*, the following table has been prepared as an aid for the disposition of the species:

TOLMERUS—KEY TO SPECIES, EXCLUSIVE OF THE MEXICAN.

1. Occipito-orbital bristles both black and yellow, gibbosity of face clothed with black and yellow bristles about equal in number... 2

   Occipito-orbital bristles all yellow, gibbosity of face mostly clothed with yellow bristles, black ones scarce if not entirely wanting.. 5

2. Femora wholly black, tibiæ and metatarsi more or less banded with red.......................................*notatus* Wied.
Femora black with preapical red band, tibiæ and metatarsi mainly red... 3
3. Second and following joints of tarsi banded with black 4
Tarsal joints wholly red or pitchy black, gibbosity of face very large, legs extra stout......................... *callidus* Will.
4. Red on femora confined to preapical band, tarsal joints annulated with black ....*annulipes* Macq.
Red on femora extending over whole length of posterior surface....................................*delusus*, n. var.
5. Femora entirely black, length of body only 10 to 12.5 mm., *mesæ*, n. sp.
Femora with red markings.. 6
6. Red on femora confined to preapical band........*prospectus*, n. sp.
Red on femora extending over whole length of posterior surface, *prairiensis*, n. sp.

Asilus tenebrosus Will. Colorado, Colorado Springs; July.

Family DOLICHOPODIDÆ.

Psilopodinus caudatus Wied. Kansas, Douglas county; May, June, July.—Colorado, Colorado Springs; August. Four anterior femora of male are yellow on distal portion for nearly one-fourth their length, more noticeable than with *scobinator* Loew, and tips of hind tibiæ are less infuscated than with that species. Both sexes.

melampus Loew. Colorado, Colorado Springs; July and August. Denver; August.

patibulatus Say. Kansas, Douglas county; July, August, September.

scobinator Loew. Kansas, Douglas county; June, twilight. One male. New to Kansas.

sipho Say. Kansas, Douglas county; May; June; June, twilight; July; July, twilight; August. Sedgwick county; August.

Diaphorus leucostoma Loew. Kansas, Douglas county; June, twilight; July.—Colorado, Colorado Springs; July, August. Denver; August.

spectabilis Loew. Kansas, Douglas county; June, twilight; July, twilight; August. New to Kansas.

Asyndetus syntormoides Wheeler. Kansas, Douglas county; July. New to the Kansas list.

Chrysotus auratus Loew. Kansas, Douglas county; June. New to Kansas.

longimanus Loew. Kansas, Douglas county; July. New to Kansas.—Colorado, Colorado Springs; August.

obliquus Loew. Kansas, Douglas county; June, twilight; July; August. New to Kansas.—Colorado, Denver; August.

pallipes Loew. Kansas, Douglas county; July, twilight. New to Kansas.

picticornis Loew. Kansas, Douglas county; August. New to Kansas.

vividus Loew. Kansas, Douglas county; May. New to Kansas.

Family DOLICHOPODIDÆ.

Porphyrops effilatus Wheeler. Colorado, Colorado Springs; July.

Sympycnus lineatus Loew. Kansas, Douglas county; May; May, at night; June; June, twilight; July, twilight. New to Kansas.

Nothosympycnus nodatus Loew. Kansas, Douglas county; June.

Dolichopus aldrichii Wheeler. Colorado, Tabernash (8310 feet); August. One male and five female specimens.

amnicola Mel. & B. Colorado, Tabernash (8310 feet); August. One female specimen.

bifractus Loew. Kansas, Douglas county; May; May, at night; June.—Colorado, Colorado Springs; August.

cuprinus Wied. Kansas, Douglas county; June; June, twilight. —Colorado, Denver; August.

eudactylus Loew. Kansas, Douglas county; June.

longipennis Loew. Kansas, Douglas county; June; June, twilight; July, twilight.

obcordatus Ald. Colorado, Colorado Springs; August. Denver; August.

plumipes Scopoli. Colorado, Tabernash (8310 feet); August.

scapularis Loew. Kansas, Douglas county; June; June, twilight; July.

variabilis Loew. Colorado, Colorado Springs; August.

vigilans Ald. Kansas, Douglas county; June (type).

vittatus Loew. Kansas, Douglas county; June, twilight. New to Kansas.

willistonii Ald. Kansas, Douglas county, June (types).

Gymnopternus crassicauda Loew. Kansas, Douglas county; June. New to Kansas.

humilis Loew. Kansas, Douglas county; June. New to Kansas.

Hercostomus unicolor Loew. Colorado, Green Mountain Falls; July.

Pelastoneurus vagans Loew. Kansas, Douglas county; June, July, August.

Family EMPIDIDÆ.

(The most recent determinations of species in this family were kindly made by Prof. A. L. Melander.)

Drapetis latipennis Mel. Kansas, Douglas county; June. New to Kansas. Specimen identified by Prof. A. L. Melander and marked "homotype" by him.

Platypalpus æqualis Loew. Kansas, Douglas county; August.—Colorado, Colorado Springs; July, August.

hastatus Mel. Colorado, Tabernash; August.

Tachydromia inusta Mel. Colorado, Manitou; August.

Specimens were found crawling on timbers which supported the roof of entrance to Grand Caverns. Prof. A. L. Melander, to whom some of the specimens were submitted, reported the name but added the following remark: "It may be that they represent an undescribed species, for their wings are more hyaline than any of the specimens of *inusta* I have."

Tachydromia pusilla Loew. Kansas, Douglas county; May.

Family EMPIDIDÆ.

Clinocera (Hydrodromia) bicincta Loew. Colorado, Colorado Springs; April.

Syneches pusillus Loew. Kansas, Douglas county; July, twilight. New to Kansas. Specimen without head, but doubtless this species.

Hybos triplex Wlk. Kansas, Douglas county; May.

Blepharoprocta (Brachystoma) serrulata Loew. Colorado, Colorado Springs; August. A single female specimen. Mr. Chas. T. Brues, who identified it, remarked that it is "quite a rare species."

Empis asema Mel. Colorado, Colorado Springs; July, August.

Determined by Prof. A. L. Melander, who wrote as follows in regard to the species: "The *Empis* was described from Austin, Tex., and yours is the first additional record of the species. Yours is somewhat larger, but I cannot find anything specific to distinguish it from the Texas form. The group to which this species belongs seems peculiar to the Southwest. There are quite a few species known with the shortened fourth vein, and all of them come from Mexico, New Mexico, Texas, and Kansas."

Empis clausa Coq. Kansas, Douglas county; June, July, August, and September, in window.

tenebrosa Coq. Colorado, Colorado Springs; July, August.

Rhamphomyia irregularis Loew. Kansas, Douglas county; April. New to Kansas.—Colorado, Colorado Springs; April.

nasoni Coq. Kansas, Douglas county; April; April, at night in house; May; May, twilight.

Family LONCHOPTERIDÆ.

Lonchoptera lacustris Meigen. (Not cited in Aldrich's catalogue.) Colorado, Tabernash; August.

This specimen was submitted to Mr. Chas. T. Brues, who reported on it as follows: "According to Schiner (Fauna Austr., I, 244), this seems very much like *L. lacustris* Meigen, an European species, as are also *lutea* and *riparia*."

Lonchoptera lutea Panz. Kansas, Douglas county; May. New to Kansas.

Family PHORIDÆ.

(My thanks are due to Mr. Chas. T. Brues for his special determinations in this family.)

Phora incisuralis Loew. Kansas, Douglas county; June, twilight (female). New to Kansas.

multiseriata Ald. Kansas, Douglas county; May. New to Kansas.

Aphiochæta agarici Lint. Kansas, Douglas county; May (male). New to Kansas.

epeiræ Brues. Kansas, Douglas county; May. New to Kansas.

longifrons Brues. (Bull. Wis. Nat. Hist. Soc., vol. IV, p. 100.) Kansas, Douglas county; June, twilight (male metatype). New to Kansas.

rufipes Meigen. Colorado, Denver; August.

Determined by Mr. Brues as "probably" this species, the single specimen having lost its wings.

Family PLAYTYPEZIDÆ.

Platypeza obscura Loew. Kansas, Douglas county; July, twilight. Determination verified by Mr. Chas. T. Brues, who says it "agrees with Loew's description except for somewhat paler halteres. The specimen is in bad shape." New to Kansas.

Platypeza pallipes Loew. Kansas, Douglas county; June. Determination verified by Mr. Chas. T. Brues, who wrote: "Agrees with the description except for darker (stained?) thorax. Undoubtedly this, I think." New to Kansas.

Platypeza velutina Loew. Kansas, Douglas county; August.—Colorado, Manitou; July.

Family PIPUNCULIDÆ.

Chalarus spurius Fal. Kansas, Douglas county; June, twilight. New to Kansas.

Pipunculus atlanticus Hough. Kansas, Douglas county; June, twilight. A female specimen which agrees well with male from Quebec, and with description, but both examples lack rows of minute black spines on anterior femora, though distinct on middle pair. New to Kansas.

cingulatus Loew. Kansas, Douglas county; August.

fuscus Loew. Kansas, Douglas county; July, twilight. New to Kansas.

nitidiventris Loew. Kansas, Douglas county; April, August.

subopacus Loew. Kansas, Douglas county; August.—Colorado, Tabernash; August.

subvirescens Loew. Colorado, Colorado Springs; August.

Family SYRPHIDÆ.

Microdon baliopterus Loew. Colorado, Garden of the Gods; July. Described as "*Omegasyrphus* sp." by Mr. W. A. Snow, in Kan. Univ. Quart., vol. III, p. 226, and specimen has label bearing name "*pullipennis* Snow." However, Doctor Williston has declared that it is merely a variation of *baliopterus* Loew.

Chrysotoxum laterale Loew, var. Kansas, Douglas county; September. New to Kansas.

Chrysogaster bellula Will. Colorado, Colorado Springs; August.

nitida Wied. Kansas, Douglas county; October.

Pipiza pistica Will. Colorado, Manitou; July.

pisticoides Will. Kansas, Sedgwick county; April. New to Kansas.

Paragus tibialis Fal. Colorado, Colorado Springs; July, August.

Myiolepta nigra Loew. Kansas, Douglas county; May, in window. New to Kansas.

varipes Loew. Kansas, Douglas county; May. New to Kansas. This specimen was examined by Prof. J. S. Hine, who reported upon it as follows: "The *Myiolepta* is small and the legs are light colored, but I think it is *M. varipes* Loew. I have a series of this species and there is great variation in size and in the color of legs. Some of my specimens are as small as yours."

Baccha clavata Fab. Kansas, Douglas county; data lost. Sedgwick county; August.

Family SYRPHIDÆ.

Ocyptamus fuscipennis Say. Kansas, Douglas county; July. New to Kansas.

Platychirus palmulosus Snow. Colorado, Colorado Springs; August (type).

peltatus Meigen. Colorado, Green Mountain Falls; July.

quadratus Say. Kansas, Douglas county; April, May.

Eupeodes volucris O. S. Colorado, Colorado Springs, Denver, Buffalo, and Tabernash; all in August.

Lasiophthicus pyrastri Linne. Colorado, Colorado Springs and Denver; August.

Syrphus abbreviatus Zett. Kansas, Douglas county; April.

americanus Wied. Kansas, Douglas county; April. Sedgwick county; August.—Colorado, Denver and Colorado Springs; August.

opinator O. S. Colorado, Denver; August.

ribesii Linne. Kansas, Douglas county; March, April, October.

Allograpta obliqua Say. Kansas, Douglas county; April; May; June; July; July, twilight; October.—Colorado, Colorado Springs; July. Cheyenne canyon; July. Denver; August.

Mesogramma geminata Say. Kansas, Douglas county; April; July, twilight.

marginata Say. Kansas, Douglas county; April; April, at night; May, at night; June; July; August.—Colorado, Garden of the Gods; July. Colorado Springs; July, August. Denver; August.

polita Say. Kansas, Douglas county; August. Sedgwick county; August.

Sphærophoria cylindrica Say. Colorado, Garden of the Gods; July. Colorado Springs; July, August.

Rhingia nasica Say. Kansas, Douglas county; June twilight. New to Kansas.

Eristalis latifrons Loew. Colorado, Colorado Springs; August.

meigenii Wied. Colorado, Colorado Springs; July, August.

temporalis Thoms. Colorado, Manitou; August.

tenax Linne. Kansas, Douglas county; October. (See remark about capture by *Phymata erosa* Linne, in "List of Hemiptera-Heteroptera.")—Colorado, Colorado Springs; August.

Helophilus lætus Loew. Colorado, Colorado Springs; August.

latifrons Loew. Colorado, Colorado Springs; August.

Syritta pipiens Linne. Kansas, Douglas county; June, July.—Colorado, Cheyenne canyon; July. Colorado Springs; July, August. Denver; August.

Spilomyia quadrifasciata Say. Kansas, Douglas county; October. (My capture of the first specimen taken in Kansas, in 1891, was regarded with surprise.)

Ceria willistonii Kahl. Kansas, Douglas county; June. A single male specimen. New to the Kansas list, although the types (all female specimens) were collected in this locality.

Family CONOPIDÆ.

Stylogaster biannulata Say. Kansas, Douglas county; June, October.

Oncomyia loraria Loew. Colorado, Denver; August.

Myopa vesiculosa Say. Kansas, Douglas county; April.

Family Œstridæ.

Gastrophilus equi Clark. Kansas, Douglas county; October, on a warm, sunny day, resting on the support of the wind instruments above the tower of a University building, 105 feet from the ground.

Family Tachinidæ.

Gymnosoma fulginosa Desv. Kansas, Sedgwick county; April.

Myiophasia ænea Wied. Colorado, Buffalo and Colorado Springs; August.

Cryptomeigenia theutis Wlk. Kansas, Douglas county; June.

Eulasiona comstockii Towns. Kansas, Douglas county; April. New to Kansas.

Plectops melissopodis Coq. Kansas, Douglas county; October. New to Kansas.

Hypostena barbata Coq. Kansas, Sedgwick county; April. New to Kansas.

Leucostoma atra Towns. Colorado, Colorado Springs; August.

Hemyda aurata Desv. Kansas, Douglas county; August, October.

Siphona geniculata De G. Kansas, Douglas county; June, twilight; July, August; August, twilight.

Heteropterina nasoni Coq. Colorado, Colorado Springs; August.

Plagia americana Van der W. Kansas, Douglas county; July, August.—Colorado, Colorado Springs; August.

Siphoplagia anomala Towns. Colorado, Colorado Springs; August.

Senotainia trilineata Van der W. Kansas, Douglas county; August.

Exorista blanda O. S. Kansas, Douglas county; June, twilight; July. New to Kansas.—Colorado, Denver; August.

griseomicans Van der W. Kansas, Douglas county; May. New to Kansas.

pyste Wlk. Kansas, Douglas county; July, twilight.

Phorocera doryphoræ Riley. Colorado, Tabernash; August.

leucaniæ Coq. Kansas, Douglas county; July. New to Kansas.

Sturmia albifrons Wlk. Colorado, Colorado Springs; August.

Acemyia dentata Coq. Kansas, Douglas county; October. New to Kansas.

Euthera tentatrix Loew. Kansas, Douglas county; July.

Tachina robusta Towns. Kansas, Douglas county; April, May. New to Kansas.

rustica Fal. Colorado, Buffalo; August.

Blepharipeza leucophrys Wied. Colorado, Colorado Springs; August.

Winthemia quadripustulata Fab. Kansas, Douglas county; May; May, at night; June; July; September; October.

Paradidyma singularis Towns. Kansas, Douglas county; May; June.

Phorichæta sequax Will. Kansas, Douglas county; April.

Metopia leucocephala Rossi. Colorado, Colorado Springs; August.

Hilarella aristalis Coq. Kansas, Douglas county; July. New to Kansas.

Gonia capitata De G., var. sequax Will. Colorado, Colorado Springs; August.

Trichophora ruficauda Van der W. Kansas, Douglas county; September.

Cuphocera furcata Van der W. Kansas, Douglas county; September.

Peletaria robusta Wied. Colorado, Buffalo; August.

tessellata Fab. Colorado, Colorado Springs; August.

Archytas analis Fab. (=Jurinia apicifera Will.) Kansas, Douglas county; June, July, September.

Family TACHINIDÆ.

Archytas aterrima Desv. (=Jurinia smaragdina Macq.) Kansas, Douglas county; September.
hystrix Fab. (=Jurinia hystricoides Will.) Kansas, Douglas county; September.
Echinomyia dakotensis Towns. Colorado, Buffalo; August.
Paradejeania rutilioides Jæn. Colorado, Colorado Springs; August.

Family DEXIIDÆ.

Myiocera cremides Wlk. Colorado, Colorado Springs; August.
Melanophora roralis Linne. Kansas, Douglas county; May, June, July, September. New to Kansas.

Family SARCOPHAGIDÆ.

(Numerous specimens await determination, since no authority cares to work with them.)

Sarcophaga (Helicobia) helicis Towns. Kansas, Douglas county; July. Sedgwick county; April. New to Kansas.—Colorado, Denver; August.

Family MUSCIDÆ.

Pollenia rudis Fab. Colorado, Colorado Springs; August.
Cynomyia cadaverina Desv. Kansas, Douglas county; April.
Calliphora erythrocephala Meigen. Kansas, Douglas county; May, common in windows; June, twilight.—Colorado, Denver; August.
latifrons Hough. Colorado, Tabernash; August.
Lucilia cæsar Linne. Kansas, Douglas county; July, October.
sericata Meigen. Kansas, Douglas county; June, twilight.—Colorado, Denver and Colorado Springs; August.
sylvarum Meigen. Kansas, Douglas county; July, twilight.—Colorado, Denver; August.
Phormia regina Meigen. Kansas, Douglas county; May, June, July.—Colorado, Denver and Tabernash; August.
Morellia micans Macq. Kansas, Douglas county; May; June; June, twilight.—Colorado, Denver and Tabernash; August.
Musca domestica Linne. Kansas and Colorado.
Stomoxys calcitrans Linne. Kansas, Douglas county; June, July, August, October.—Colorado, Tabernash; August.
Myospila meditabunda Fab. Colorado, Tabernash; August.
Muscina stabulans Fal. Kansas, Douglas county; April; June; June, twilight; July, twilight.—Colorado, Denver, Tabernash, and Colorado Springs; August.

Family ANTHOMYIDÆ.

Hyetodesia (Phaonia) mulcata? Giglio-Tos. Kansas, Douglas county; April. New to Kansas.
Limnophora narona Wlk. Kansas, Douglas county; June; July; July, twilight. Sedgwick county; April. New to Kansas.—Colorado, Green Mountain Falls; July. Colorado Springs; July, August. Denver and Tabernash; August.
Hylemyia lipsia Wlk. Kansas, Douglas county; April; June; July; July, twilight; August. New to Kansas.

Family ANTHOMYIDÆ.

Phorbia cinerella Fal. Kansas, Douglas county; May.—Colorado, Colorado Springs; April. Denver and Tabernash; August.

fusciceps Zett. Kansas, Douglas county; April; April, at night; June; June, twilight. Sedgwick county; April. New to Kansas.—Colorado, Colorado Springs; April. Denver; August.

Cœnosia lata Wlk. (=canescens Stein, as Mr. Coquillett determined it). Kansas, Douglas county; April, July, August. New to Kansas.

Schœnomyza dorsalis Loew. Kansas, Douglas county; May, June. New to Kansas.—Colorado, Colorado Springs; July, August. Tabernash; August.

Family SCATOPHAGIDÆ.

Scatophaga furcata Say. Kansas, Douglas county; April; May, at electric light.

Family HELOMYZIDÆ.

Leria pectinata Loew. Kansas, Douglas county; April, at night. New to Kansas.

Family BORBORIDÆ.

Limosina atra Adams. Kansas, Douglas county; July, at electric light on bridge across Kansas river in Lawrence (type).—Colorado, Colorado Springs and Tabernash; August (compared with type).

Limosina evanescens, new species. Kansas, Douglas county; June; June, twilight; July, at electric light. Types: Four specimens; one deposited in the United States National Museum, Washington, D. C., the others in the collection of the University of Kansas. For the Kansas list. Six metatypes: Brookings, S. Dak., collected by Prof. J. M. Aldrich.

In perfect mature condition, such as is presented by most of my examples, the body and legs are almost wholly dullish black, about the only deviation being a tawny color of the legs, especially the middle tarsi, besides some spots on the pleura. Any portion of the body that shines has suffered denudation of its pollinose coating. The dorsum of thorax is clothed with numerous black bristles and short, stubby hairs; front of head also bristly. Scutellum flat, with two long bristles near apex and one on each side near base.

Antennæ wholly black, except very fine grayish pubescence on the long arista, the third joint vertically reniform, with the second joint enlarged against it and fitting into the concavity; both of these joints with bristly hairs.

The metatarsal joint of the hind legs is only slightly incrassate, as the brush-like pubescence underneath makes the size deceptively large. In length it is more than half as long as the second joint, which is also pubescent beneath.

Wings uniformly hyaline, though in some cases with a feeble yellowish tinge, especially in the marginal cell. The second vein joins the costa with a more or less deflecting curve at or slightly beyond half the distance between tip of first and third vein. Fourth vein evanescent, the fifth short appendiculate beyond the discal cell. Third longitudinal vein perfectly straight with one specimen, ending at a point almost

Family BORBORIDÆ.

Limosina evanescens—*continued.*

at extreme apex of wing, but with the other specimens it is very gently curved forward at tip; the costal vein always extends on to apex.

Length, 1.5 mm.

Limosina fontinalis Fal. Kansas, Douglas county; April, at night; July, at electric light; August.—Colorado, Colorado Springs; April, August. Tabernash; August.

Limosina obfuscata, new species. Colorado, Colorado Springs (5915 feet); August, 1906. Type: One female specimen in the collection of the University of Kansas.

Body and legs deep opaque black, excepting tawny color of the tarsi of middle legs, posterior coxæ largely, middle coxæ slightly, all the trochanters, and the knees, also halteres, which are paler, besides some spots or markings on the pleuræ. Where rubbed, however, the surface is shining. Dorsum of thorax clothed with numerous black bristles and short, stubby hairs, likewise the front of the head. Scutellum flat, bearing eight bristles arranged as follows: Two long ones close to the apex and a group of three on each side near the base; the middle bristle in this group is similar to the apical ones, and the one in front is quite short, but the other, which stands behind, is of medium length.

Antennæ wholly black, including the long arista, which, however, has extremely fine grayish pubescence; third joint large and ovate, bearing several bristly hairs. Femora of fore legs ciliate behind, tibiæ of middle legs bristly, short cilia on tibiæ of posterior legs; hind metatarsi not much dilated, two-thirds as long as the second joint, both of these joints with fulvous, brush-like pubescence on under side.

Wings smoky tinged, a faint cloud enveloping apical curve of second vein, which joins the costa considerably more than half the distance between the tip of first and third veins; third vein curves gently forward and terminates some distance before the apex of the wing; all veins black, the fourth being distinctly indicated beyond the discal cell. Edge of first section of costa fringed with bristles, second section distinctly and the third finely ciliate.

Length, 2.3 mm.

Borborus equinus Fal. Kansas, Douglas county; April; April, at night; May, at night and at electric light.—Colorado, Colorado Springs; April. Tabernash; August.

geniculatus Macq. Colorado, Colorado Springs; August.

Sphærocera subsultans Fab. Colorado, Colorado Springs; April.

Family SCIOMYZIDÆ.

Sciomyza nana Fal. Kansas, Douglas county; May, at night.

obtusa Fal. Kansas, Douglas county; June. New to Kansas.

Tetanocera costalis Loew. Kansas, Douglas county; May.

umbrarum Linne (= pictipes Loew). Kansas, Douglas county; April; May, at night. Sedgwick county; September, sweepings in slough-grass in timber along Arkansas river.

Sepedon armipes Loew. Kansas, Sedgwick county; sweepings in slough-grass in timber along Arkansas river.—Colorado, Colorado Springs; August.

fuscipennis Loew. Colorado, Colorado Springs; August.

Family SAPROMYZIDÆ.

Lonchæa polita Say. Kansas, Douglas county; April, May, June, July, September, October (common in windows).

vaginalis Fal. (Not listed in Aldrich's catalogue.) Kansas, Douglas county; June. New to Kansas.

Pachycerina dolorosa Will. Colorado, Green Mountain Falls; July. Colorado Springs; July, August.

Lauxania gracilipes Loew. Kansas, Douglas county; July, twilight. New to Kansas.

Sapromyza innuba? Giglio-Tos. Kansas, Douglas county; April. New to Kansas.

quadrilineata Loew. Kansas, Douglas county; April. New to Kansas.

tenuispina Loew. Kansas, Douglas county; June.—Colorado, Denver; August.

vulgaris Fitch. Kansas, Douglas county; June, twilight; July; July, twilight. Sedgwick county; May and September, in thicket along Arkansas river.—Colorado, Colorado Springs; July.

Family ORTALIDÆ.

Rivellia micans Loew. Kansas, Douglas county; June.

quadrifasciata Macq. Kansas, Douglas county; July.

Camptoneura picta Fab. Kansas, Douglas county; May; June; July; August, twilight.

Melieria obscuricornis Loew. Colorado, Colorado Springs; July, August.

Tetanops integra Loew. Kansas, Douglas county; May. New to Kansas.

luridipennis Loew. Kansas, Douglas county; June.

Pterocalla strigula Loew. Kansas, Douglas county; May, August.

Callopistria annulipes Macq. Kansas, Douglas county; May.

Pseudotephritis cribrum Loew. Kansas, Douglas county; May, August, September.

vau Say. Kansas, Douglas county; June. New to Kansas.

Œdopa capito Loew. Colorado, Colorado Springs; July, August.

Euxesta notata Wied. Kansas, Douglas county; July. Sedgwick county; April.

Chætopsis ænea Wied. Kansas, Douglas county; May; May, twilight; August; August, twilight; October. Sedgwick county; April.—Colorado, Colorado Springs; August.

Seoptera vibrans Linne. Kansas, Douglas county; June. New to Kansas.

Eumetopia rufipes Macq. Kansas, Douglas county; August, twilight and at night.

Family TRYPETIDÆ.

Straussia longipennis Wied. Kansas, Douglas county; May; June, twilight; July, twilight.—Colorado, Colorado Springs; July.

Spilographa flavonotata Macq. Colorado, Manitou; July.

Rhagoletis pomonella Walsh. Colorado, Colorado Springs; August.

Neaspilota alba Loew. Kansas, Douglas county; July.—Colorado, Colorado Springs; August.

Ensina humilis Loew. Colorado, Colorado Springs; August.

Family TRYPETIDÆ.

Tephritis finalis Loew (= "affinis Snow." The label is thus marked, probably by Mr. W. A. Snow himself, thereby indicating that the name he bestowed is a synonym.) Colorado, Colorado Springs; July.

Euaresta æqualis Loew. Colorado, Colorado Springs; July, August.

bella Loew. Kansas, Douglas county; July, August.

festiva Loew. Kansas, Douglas county; August.

tapetis Coq. Colorado, Colorado Springs; August.

Urellia abstersa Loew. Colorado, Colorado Springs; July, August.

actinobola Loew. Kansas, Douglas county; September, at night.—Colorado, Colorado Springs; August.

bisetosa Coq. Colorado, Colorado Springs; August.

pacifica Doane. Colorado, Colorado Springs; August.

solaris Loew. Colorado, Colorado Springs; August.

Family MICROPEZIDÆ.

Micropeza turcana Towns. Colorado, Colorado Springs; August.

Calobata antennipes Say. Kansas, Douglas county; June, twilight.

Family SEPSIDÆ.

Sepsis violacea Meigen. Kansas, Douglas county; June, July. Sedgwick county; April, May.—Colorado, Colorado Springs; July, August.

Nemopoda minuta Wied. Kansas, Douglas county; June, twilight; July; July, twilight. New to Kansas.—Colorado, Colorado Springs; August.

Piophila casei Linne. Kansas, Douglas county; April, reared from larvæ received in infested ham from packing-house in Kansas City, Kan., and bred on both ham and cheese.—Colorado, Colorado Springs; April, July, and August, sweepings.

Family PSILIDÆ.

Chyliza apicalis Loew. Kansas, Douglas county; June, twilight. New to Kansas.

Family EPHYDRIDÆ.

Paralimna appendiculata Loew. Kansas, Sedgwick county; September.—Colorado, Colorado Springs; July, August.

Hyadina albovenosa Coq. Kansas, Douglas county; April, at night. New to Kansas.

Ochthera mantis De G. Colorado, Colorado Springs; August.

Parydra bituberculata Loew. Colorado Springs; April.

Family OSCINIDÆ.

Meromyza americana Fitch. Kansas, Douglas county; July, August.—Colorado, Colorado Springs; July.

Chlorops (Diplotoxa) alternata Loew. Colorado, Green Mountain Falls; July. Colorado Springs; August.

assimilis Macq. Kansas, Douglas county; June; June, twilight; July; July, twilight. Sedgwick county; April.—Colorado, Colorado Springs; July, August. Denver; August.

obscuricornis Loew. Colorado, Manitou; August.

Family OSCINIDÆ.

Chlorops palpalis Adams. Kansas, Douglas county; May, twilight. New to Kansas.

pullipes Coq. Kansas, Sedgwick county; September, sweepings in pear orchard.—Colorado, Tabernash; August. Colorado Springs; August.

scabra Coq. Colorado, Tabernash; August.

unicolor Loew. Kansas, Douglas county; June, twilight. Sedgwick county; September.

variceps Loew. Colorado, Green Mountain Falls; July.

Hippelates flavipes Loew. Kansas, Douglas county; June. Sedgwick county; April. New to Kansas.

plebeius Loew. Colorado, Colorado Springs; August.

pusio Loew. Kansas, Douglas county; June, twilight; August. Sedgwick county; April. New to Kansas.

Elachiptera costata Loew. Kansas, Douglas county; April, May, June; June, twilight. Sedgwick county; April.—Colorado, Colorado Springs; August.

longula Loew. Kansas, Sedgwick county; April.

Oscinis carbonaria Loew. Kansas, Douglas county; April, at night; May, at night. New to Kansas.

coxendix Fitch. Kansas, Douglas county; April; June, twilight. Sedgwick county; April. New to Kansas.

decipiens Loew. Kansas, Douglas county; July. New to Kansas.

nudiuscula Loew. Kansas, Douglas county; August.

pallipes Loew. Kansas, Douglas county; June, August.

soror Macq. Kansas, Douglas county; May, June. New to Kansas.

variabilis Loew. Kansas, Douglas county; June, twilight; July.

Family DROSOPHILIDÆ.

Drosophila (Scaptomyza) adusta Loew. Kansas, Douglas county; May, at night; August. New to Kansas.—Colorado, Colorado Springs; August.

amœna Loew. Kansas, Douglas county; April. New to Kansas.

ampelophila Loew. Kansas, Douglas county; August, October, November; noxious in kitchen and other rooms of house wherever fruit and cider were exposed.—Colorado, Denver; August; attracted to exposed fruit on table in house, both day and night.

funebris Fab. Kansas, Douglas county; May; June; July; July, twilight; October; November, in kitchen. New to Kansas.

(Scaptomyza) graminum Fal. Kansas, Douglas county; April; April, at night. New to Kansas.

Family AGROMYZIDÆ.

Phytomyza diminuta Wlk. Kansas, Douglas county; May; June, twilight and at night. New to Kansas.—Colorado, Denver and Colorado Springs; August.

Ceratomyza dorsalis Loew. Kansas, Douglas county; May, at electric light; June. New to Kansas.—Colorado, Colorado Springs; August.

Family AGROMYZIDÆ.

Agromyza æneiventris Fal. Kansas, Douglas county; July. New to Kansas.

parvicornis Loew. Kansas, Sedgwick county; April. New to Kansas.

Desmometopa latipes Meigen. Kansas, Douglas county; June. New to Kansas.

m-nigrum Zett. Kansas, Douglas county; June. New to Kansas.

Ophthalmomyia lacteipennis Loew. Kansas, Sedgwick county; August, in windows of farmhouse. New to Kansas.

TABULATED SUMMARY OF FAMILIES AND SPECIES, INCLUDING VARIETIES.

NAME OF FAMILY.	Total number of species.	Species taken in Kansas.	Species new to Kansas.	Species taken in Colorado.	Species taken in both Kansas and Colorado.
Tipulidæ	4	5	2	2	2
Psychodidæ	1	1	....	....	....
Chironomidæ	37	35	31	6	4
Culicidæ	* 15	14	6	4	3
Mycetophilidæ	9	7	3	2	....
Cecidomyidæ	†	....	....	....	....
Bibionidæ	9	9	5	1	1
Rhyphidæ	2	2	2	....	....
Stratiomyidæ	8	6	2	4	2
Tabanidæ	7	5	1	2	....
Leptidæ	7	3	....	5	1
Bombyliidæ	24	6	....	20	2
Therevidæ	2	2	1	....	....
Sceneopinidæ	1	1	....	....	....
Mydaidæ	1	1	....	....	....
Asilidæ	26	15	7	13	2
Dolichopodidæ	34	26	13	14	6
Empididæ	14	8	3	8	3
Lonchopteridæ	2	1	1	1	....
Phoridæ	6	5	5	1	....
Platypezidæ	3	3	2	1	1
Pipunculidæ	7	6	3	2	1
Syrphidæ	35	20	7	20	5
Conopidæ	3	2	....	1	....
Œstridæ	1	1	....	....	....
Tachinidæ	39	25	9	16	2
Dexiidæ	2	1	1	1	....
Sarcophagidæ	1	1	1	....	....
Muscidæ	13	10	....	11	8
Anthomyidæ	7	7	6	4	4
Scatophagidæ	1	1	....	....	....
Helomyzidæ	1	1	1	....	....
Borboridæ	7	4	1	6	3
Sciomyzidæ	6	5	1	2	1
Sapromyzidæ	8	7	4	3	2
Ortalidæ	15	13	3	3	1
Trypetidæ	15	5	....	13	3
Micropezidæ	2	1	....	1	....
Sepsidæ	3	3	1	3	3
Psilidæ	1	1	1	....	....
Ephydridæ	4	2	1	3	1
Oscinidæ	21	16	7	9	4
Drosophilidæ	5	5	4	2	2
Agromyzidæ	7	7	7	2	2
Totals (44 families)	416	299	142	186	69

*Syn. 1?. †Undetermined.

NOTE.—My lists as presented give all the results obtained in the orders treated so far as the specimens have been identified up to this time. A considerable amount of material yet remains to be reported upon, especially in the order Hymenoptera, and, as additions are constantly being made, the task of making known the facts will be unending, if carried on.

APPENDIX.

SOME NEW SPECIES OF KANSAS CHIRONOMIDÆ.

By O. A. Johannsen.

Among a lot of Chironomidæ submitted to me for identification by Mr. E. S. Tucker, of the museum of the University of Kansas, were several specimens which could not be classified with any previously described species, and are therefore presented here as new.

Bezzia elegantula, n. sp.

Female.—Head and proboscis yellowish, the tip of the latter and the palpi fuscous. Eyes nearly contiguous over the base of the antennæ. Antennæ, including the large basal joint, yellow. Thorax deep yellow, subshining, humeri and pleura with a grayish bloom; dorsum with four rows of fine setæ, also a marginal row near the base of the wing. Abdomen yellowish brown, posterior segments a little darker, posterior margins of all the segments pale yellow; venter yellow, posterior margins of the segments on the sides black. Legs, including coxæ, yellow; tips of hind femora, bases of hind tibiæ and tips of all tibiæ brown; tips of all tarsal joints also narrowly brown. Claws very unequal, under side of fifth tarsal joint of all the feet with one or two pairs of stout, blunt, black spines; hairs of all tibiæ and tarsi black. Wings bare, pale, veins yellow; the tip of the radius ends about one-fourth of the wing length from apex; the media petiolate, the stem but little shorter than the cross-vein. Halteres yellow, with pale green knob. Length, 2 mm. Collected in July at electric light on bridge across Kansas river at Lawrence, Douglas county, Kansas, by E. S. Tucker.

The homology of the Ceratopogon wing venation given on plate 17, figures 13 to 16 (Bulletin 86, New York State Museum), I now believe to be incorrect. What is marked R_{2+3} should be R_{4+5}, while those marked R_{4+5} and M constitute the anterior and posterior branches of the media.

Ablabesmyia aurea, n. sp.

FEMALE.—Head black; proboscis and palpi reddish yellow; antennæ wholly yellow with yellow hairs. Thorax, including pleura, sternum, metanotum, and scutellum, dull black; humeral spots yellowish; thoracic hairs pale. In one specimen the scutellum is brownish and there is an indication of two slender yellow lines upon the mesonotum. Abdomen wholly golden yellow. Coxæ golden yellow, legs wholly pale yellow. Wings, their veins and hairs with a yellowish tinge; R_1 connected with R_3 a short distance before its tip by the oblique R_2. Halteres yellow. Length, 2.5 mm.

Collected by E. S. Tucker, at Lawrence, Douglas county, Kansas, in July, at electric light on bridge across Kansas river.

Chironomus lucifer, n. sp.

MALE.—Head and mouth parts testaceous, upper surface of proboscis infuscated, basal joints of antennæ yellow (flagellum broken off). Thorax yellowish, more testaceous in some lights, somewhat shining, the dorsal stripes wide, deep brownish black, the median one prolonged from collar to scutellum, the laterals abbreviated anteriorly but extending to the root of the wing posteriorly; the humeri conspicuously yellow; metanotum and pectus brownish black, scutellum yellowish. Anterior segments of the abdomen grass green, almost unicolored, the last three segments broadened, infuscated. Genitalia small and slender, resembling those of *C. modestus* (plate 32, figure 8, Bulletin 86, New York State Museum), both superior and inferior lobes having enlarged ends, but the latter with more conspicuous setæ. Legs yellowish with a greenish tinge; base of fore femora, tips of all tibiæ and all tarsal joints more or less infuscated, some of the apical joints wholly infuscated. Empodium brush-like, as long as the claws. (Fore tarsi broken off.) Wings hyaline with a yellowish tinge, veins yellow, cross-vein not darkened; cubitus forks slightly distad of the cross-vein. Halteres pale yellow. Length, 3 mm.

FEMALE.—Differs from the male as follows: Antennæ yellow, apical joint black; dorsal thoracic stripes more confluent; abdomen wholly yellow. Legs yellow, apical half of

the fore tibiæ and tips of the tarsal joints brown, the last three joints of the fore tarsi wholly brown; the paler portion of the tarsi whitish. Fore metatarsus one-third longer than its tibia.

Taken at electric light, in July, on bridge crossing Kansas river at Lawrence, Douglas county, Kansas, by E. S. Tucker.

Chironomus flaviventris, n. sp.

MALE.—Resembles *C. flavus*, but differs in having darker thoracic stripes. Head testaceous; antennæ yellow, basal joint testaceous, mouth-parts yellow. Thorax, including scutellum, metanotum, sternum, and pleura, pale brown, the humeri and the space between the dorsal stripes more yellowish. Abdomen pale yellow, apical joints slightly darkened. Genitalia yellow, slender, the lateral arms lanceolate. Legs wholly pale yellow. All hairs of abdomen and legs pale yellow. Fore metatarsus twice as long as its tibia. Wings cream white, veins colorless. Halteres pale. Length, 2.5 mm.

FEMALE.—Like the male, but shorter, stouter, and with broader wings. In two specimens the thoracic stripes are dark brown.

Collected at Lawrence, Douglas county, Kansas, in July, at electric light on bridge across Kansas river, by E. S. Tucker.

Chironomus attenuatus WALKER.

Two female specimens, which I doubtfully refer to this species and which agree very well with Walker's description, may be further characterized as follows: Antennæ yellowish; humeri, space between the thoracic stripes and the scutellum yellowish gray; posterior margins of the abdominal segments more or less distinctly light gray. Fore metatarsus one-half longer than its tibia; knees and middle and hind tibiæ brownish.

Collected by E. S. Tucker, at Lawrence, Douglas county, Kansas; June; July, at electric light; August.

Metriocnemus exagitans JOHANNSEN.

The description of the wing given in Bulletin 86, New York State Museum, on page 303, as also the figure 4, plate 31, was made from a defective wing. Line 3 from the bottom of the page should read: "R_{4+5} ends some distance from the tip of the wing." The female resembles the male, but is shorter, stouter, and has broader wings.

Several specimens from Lawrence, Douglas county, Kansas; collected by E. S. Tucker; March, April, and April at night.

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INVERTEBRATE PALEONTOLOGY OF THE UPPER PERMIAN RED BEDS OF OKLAHOMA AND THE PANHANDLE OF TEXAS.

BY J. W. BEEDE.[1]

With plates V to VIII.

THROUGH the favor of Prof. E. Haworth the writer was enabled to study the Red Beds of western Oklahoma and the Panhandle of Texas in the latter part of the season of 1904. The locality at Whitehorse spring, eighteen miles west of Alva, Okla., was visited and a collection of fossils secured from the Whitehorse sandstone. In addition to this, the rocks of the Quartermaster formation, now known to form the upper part of the Paleozoic Red Beds, were studied, and a collection made from the sandstone exposed near Dozier, Tex., at a place noted previously by Prof. C. N. Gould. This sandstone is shown in the hills just east of Mr. Caperton's house, which was then the post-office of Dozier. The fossils were found on the west slope of the hill.

On account of unavoidable delays the results of the study of these collections have been postponed to the present time. These collections are of great importance, as they furnish the final evidence that the Red Beds, below the Dockum beds, of the Oklahoma-Panhandle region are Paleozoic in age. Before entering into a detailed discussion of the fauna of these rocks and their relationships and the age of the deposits, it is desirable to give a brief review of previous work upon the subject. Much of this has been given by Prof. W. F. Cummins, in the Second Annual Report of the Geological Survey of Texas, and is liberally quoted below.

1. Published by permission of the Director of the Geological Survey of Kansas.

HISTORICAL REVIEW.

Prior to the work of the Texas Geological Survey and the work of Cope and White, the Red Beds were referred to one system or another on lithologic and stratigraphic evidence alone. The first of these criteria is of very little value when the rocks are as isolated from the ones with which they are correlated as are the western Red Beds. Their stratigraphic position is such that, until fossils were found, and the fact discovered that they are largely conformable with the Permian and Pennsylvanian below was made known, they could be referred to anything from the Permian to the Tertiary. All these possibilities were suggested by one author or another.

About the earliest work done on these rocks was by Dr. C. G. Shumard, a member of the expedition of Capt. R. B. Marcy, in 1852.[2] Shumard made no attempt to assign any age to these beds, but gave sections and descriptions of them. Prof. Edward Hitchcock studied Doctor Shumard's lithologic specimens and notes, and suggested the difficulty in assigning the proper age to them. He stated[3] that "from the 3d of May to June 2, the formation passed over is, as I judge from Doctor Shumard's sections and descriptions, the predominant one along the upper part of the Red river. All the appended sections of Doctor Shumard, except Nos. VI and XI, exhibit the characters and varieties of this deposit. Red clay is the most striking and abundant member; and above this we have a yellow or lighter-colored sandstone, often finely laminated. As subordinate members, we have blue and yellow clay, gypsum, non-fossiliferous limestone, conglomerate, and copper ore. Overlying these strata is what Doctor Shumard calls 'drift,' which is surmounted by soil. Excepting the gypsum and copper, no specimen of this formation was put into my hands; and only one petrifaction, which is a coral from the base of No. 4, unless the fossil wood belongs to it."

After discussing the coral supposed to come from "the base of section No. IV" and a piece of fossil wood, he concludes: "Upon the whole, I rather lean to the opinion that

2. Exploration of the Red River of Louisiana, in the year 1852. Published in 1854.

3. Op. cit., p. 145.

these strata may belong to the Cretaceous formation, though it is singular, if such be the case, that the fossil remains are so scarce, since, as we shall see, they occur abundantly in another portion of the field in which the Cretaceous rocks abound."

Prof. Jules Marcou was the first man to refer these rocks to the Permian, though he first referred them to the Triassic. He states:[4] "Immediately after crossing Delaware Mount . . . we met with horizontal beds of red and blue clay that belong to another geological epoch; this new formation corresponding to that which European geologists have agreed to call the Trias." Four years later he thought that a portion of these beds was Permian, and states: "I have always strongly suspected that the New Red Sandstone between Delaware Mount and Beaverton was of Permian age. Having found no fossils, and being the first geologist to enter these regions, I was not able when in the field to declare exactly the age of those strata. All that I knew was that after having left the Carboniferous limestone of Delaware Mount I entered upon another and younger formation, and it was only after having passed Beaverton that I saw clearly that I was upon the New Red Sandstone. Since the discovery of Permian in Kansas I am still more inclined to the belief that the strata between Delaware Mount and Beaverton are Permian. Thus, you see, I include the Permian in the New Red Sandstone."[5]

In a paper on the notes furnished him by Capt. John Pope on a survey from El Paso to Preston he says: "The upper part and the head waters of the Rio Brazos are situated on the rocks of the Trias." "I have since used the more general expression New Red Sandstone formation to designate all the strata in America between the Carboniferous formation and the Jurassic rocks." These statements would seem to indicate that he considered the lower portion of the Red Beds as Permian and those higher up as Triassic. These correlations were based upon lithological and stratigraphical grounds, as stated by Cummins.[6]

4. Report of Explorations for a Railroad Route near the Thirty-fifth Parallel of Latitude, 1854.

5. American Geology, Zurich, 1858. From Cummins.

6. Sec. Ann. Rep. Geol. Surv. Tex., p. 399, 1891.

"Dr. William De Ryee, formerly state chemist, visited Archer county in 1868, in the interests of the Texas Copper Mining and Manufacturing Company. In a report made to that company, and published by them, he says: 'After traversing the Lyas and Carboniferous series northward of Weatherford, I was agreeably surprised by a grand panorama of the outcropping of the Permian formation. This system is extensively developed in Russia between the Ural mountains and the river Volga, in the north of England, and in Germany, where it is mined for its treasures of copper, silver, nickel and cobalt ores. It has not heretofore been known to exist in this state, or has been mistaken for the Triassic system, which is overlying the former to the northwest.'

"Prof. Jacob Boll, formerly of Dallas, Tex., in an article entitled 'Geological Examinations in Texas,' published in the *American Naturalist*, vol. XIV, pp. 684–686, September, 1880, says that these beds of Texas are undoubtedly Permian.

"Prof. G. C. Broadhead, who visited Colorado City, refers the beds in the vicinity of that place to the Permian."[7]

Professor Boll's statement quoted above probably has its foundation in the collecting and exploring which he did for Professor Cope, and who secured some of the material described by Cope and listed below.

Cope was the first to refer the Red Beds to the Permian, using fossils as evidence of their age. In 1878 he published an article stating that "the discovery of a species of the genus *Clepsydrops* in Texas, in a formation hitherto regarded as Triassic, adds weight to the view above expressed, that the Clepsydrops shales of Illinois belong either to the Triassic or to the Permian formation."[8] In the same year, under the title "Descriptions of Extinct Batrachia from the Permian Formation of Texas," he describes the following species:[9] *Diadectes sideropelicus*, *D. latibuccatus*, *Bolosaurus striatus*, *Chilonyx* (*Bolosaurus*) *rapidens*, *Pariotichus brachyops*, *Pariotichus* (*Ectocynodon*) *ordinatus*, *Clepsydrops natalis*, *Dimetrodon incisivus*, *D. rectiformis*, *D. gigas*, *Eryops* (*Epicordylus*) *erythroliticus*, *Meta-*

7. Taken from Geol. Surv. Tex., 2d Ann. Rep., pp. 399, 400.

8. Proc. Amer. Phil. Soc., XVII, p. 193.

9. Ibid., pp. 505–530. Lists revised after Hay.

mosaurus fossatus, *Empedias* (*Empedocles*) *alatus*, *Embolophorus fritillus*, *Threopleura retroversa*, *T. uniformis*, *T. triangulata*, *Eryops megacephalus*, *Eryops* (*Parioxys*) *ferricolus*, *Cricotus heteroclitus*, *Zatrachys serratus*, *Trimerorhachis insignis*, *Rhachitomus valens*, *Ctenodus periprion*, *C. porrectus*, *C. dialophus*. Based on these fossils, he states the following "thesis," among others: "The horizon of the Clepsydrops shales of Illinois and the corresponding beds in Texas is Permian." Under the title "Second Contribution to the History of the Vertebrata of the Permian Formation of Texas," he adds the following species:[10] *Theopleura obtusidens*, *Naosaurus* (*Dimetrodon*) *cruciger* (described in Amer. Nat., 1878), *Diadectes phaseolinus*, *Empedocles molaris* (ibid.), *Helodectes paridens*, *Parabatrachus* (*Ectosteorachis*) *nitidus*. In 1883 he published his third contribution,[11] adding the following species without discussion: *Edaphosaurus pogonias*, *Pariotichus* (*Ectocynodon*) *aguti*, *Diplocaulus magnicornis*, *Acheloma cumminsi*, *Anisodexis imbricarius*.

In the same volume, on page 628, he publishes his fourth contribution, adding the following species, which he considers as Permian, adding them without discussion of their age: *Parabatrachus* (*Ectosteorachus*) *ciceronius*, *Gnathorhiza serrata*, *Trimerorhachis bilobatus*, *Isodectes* (*Pariotichus*) *megalops*, *Chilonyx rapidens*, *Empedias* (*Empidens*) *fissus*, *Diadectes* (*Empidens*) *phaseolinus*. In the fifth contribution he adds "and Indian Territory" to the title. His additions are:[12] *Ceratodus favosus*, *Cricotus crassidicus*, *C. hypantricus*, *Clepsydrops leptocephalus*, *C. macrospondylus*, *Naosaurus* (*Edaphosaurus*) *microdus*, *Diacranodus* (*Didymodus*) *texensis* (= *D. compressus*?), *D.* (*D.*) *platypternus*, *Embolophorus dollovianus*. In 1892 he remarks that the Dockum beds are Triassic, basing his conclusions on fossils secured from them.[13] In various other places he refers to the lower beds where the fossils were obtained as Permian, the Dockum beds being above the unconformity at the top of the Permian beds. In other papers Cope adds the following species to his list from the Texan Permian: *Pariotichus isolomus*, *Pantylus cordatus*, *P. coicodus*,

10. Ibid., XIX, pp. 35-38, 1880.

11. Ibid., XX, p. 447.

12. Ibid., XXII, pp. 28-47, 1885.

13. Ibid., XXX, pp. 123-131.

Hypopnous squaliceps, *Zatrachys microthalamus*, *Z. conchigerus*, *Trimerorhachis mesops*, *Diplocaulus limbatus*, *Octocœlus testudineus*, *O. mimeticus*, *Conodectes favosus*, *Diadectes biculminatus*, *Bolbodon tenuitectus*, *Pariotichus aduncus*, *Labidosaurus hamatus*, *Trimerorhachis conangulus*, *Pariotichus* (*Ectocynodon*) *incisivus*, *Helodectes isaaci*, *Platysomus palmaris*, *Ctenacanthus amblyxiphias*, *Janassa ordiana*, *Dimetrodon semiradicatus*, *Naosaurus claviger*.

Aside from Cope's "Contributions," Cummins quotes a statement of his[14] concerning the age of the beds he refers to the Permian, which is as follows: "The Texan genera of this group, so far as known, are equally related to the Ural and South African types. The age of the former deposit is the Permian, which includes, according to Murchison, the Rodthliegende and Zechstein of Thuringia. The age of the South African beds is uncertain, but it is suspected by some authors to be Triassic, and by Owen to be Paleozoic. In discussing the age of the Clepsydrops shales of Illinois, which had been referred to the Coal Measures by all previous investigators, I left the question open as to whether they should be referred to the Permian or Triassic formations. The evidence now adduced is sufficient to assign the formation, as represented in Illinois and Texas, to the Permian. Besides the saurian genera, above mentioned, the existence of the ichthyic genera *Janassa*, *Ctenodus* and *Diplodus* in both localities renders this course necessary."

In the February number of the *American Naturalist* for 1889,[15] Prof. Charles A. White described the first invertebrates from the Red Beds of Texas. The fossils were from the same horizon as the vertebrates described by Cope, above mentioned. Specimens were first submitted to White by Prof. W. F. Cummins, who did much of the collecting for Cope. White then visited the localities from which the specimens came and, with Cummins, made further collections. He also studied the stratigraphy of the region and published the section made by Cummins, and verified by himself, of the rocks of the region in which the fossils were found. On page 113

14. Geol. Surv. Tex., II, p. 414.

15. XXIII, pp. 109-128.

he says: "The following section of the Texas Permian is taken from Mr. Cummins's field-notes, but it has been in large part verified by my own personal observation. The different members of this section, which are indicated by consecutive numbers, are not distinctly definable from one another, but the section is presented in this form for convenience in making reference to the respective horizons at which collections of fossils have been made." The section follows:

"1. Reddish and mottled sandy clays, with occasional layers of sandstone.

"2. Variously colored clayey and sandy concretionary strata, with a few irregular layers of impure concretionary limestone; embracing near its middle a somewhat persistent limestone of grayish-blue color.

"3. Sandstones alternating with clayey and sandy concretionary layers and a few fine-grained siliceous layers.

"4. Reddish and buff colored clayey and sandy shales, with occasional layers of sandstone.

"5. Sandstones and sandy shales, with beds of reddish sandy clay, passing gradually into the Coal Measures beneath."

"Vertebrate remains, which Professor Cope confidently refers to the Permian, occur at numerous localities and many horizons from the base to the top of this section; but invertebrate remains have hitherto been discovered only in strata which are included in Nos. 2 and 3, respectively, of that section. The lowermost known horizon of invertebrates is about 400 feet above the base of the series, and the uppermost is about as much below the top of the same; that is, the middle 200 feet in thickness of the Permian series as it has been defined."

He then proceeds to give the localities from which the fossils were secured. He then gives a list of thirty-two species from these two horizons, shown in tabular view, from three localities. His list is as follows: *Goniatites baylorensis*, *Ptychites cumminsi*, *Medlicottia copei*, *Popanoceras walcotti*, *Orthoceras rushensis?*, *Nautilus winslowi*, *N. occidentalis*, *N.* three undetermined species, *N.* (*Endolobus*) undetermined, *Nati-*

copsis remex, *N. shumardi?*, *Euomphalus subquadratus*, *E.* undetermined, *Murchisonia* and *Patella* both undetermined, *Bellerophon crassus*, *B. montfortianus* and one undetermined, *Sedgwickia topekaensis*, *Pleurophorus* undetermined, *Clidophorus occidentalis*, *Yoldia subscitula*, *Myalina permiana*, *M. aviculoides*, *M. perattenuata*, *Gervillia longa*, *Aviculopecten occidentalis*, *Syringopora*, *Spirorbis* undetermined, and *Cythere nebrascensis*."

Concerning *Ptychites cumminsi* and *Popanoceras walcotti*, he remarks, "that if they alone, and without any statement of correlated facts, had been submitted to any paleontologist, he would not have been warranted in referring them to an earlier period than the Trias, if he had followed the usually accepted standard of reference." His conclusion is, after an extended discussion of the Permian and Carboniferous of the world: "The evidence upon which the Texan strata have been referred to the Permian is fuller than that which has been adduced with regard to any other North American strata that have been so referred; that is, the evidence of both vertebrate and invertebrate fossils is in favor of such reference, and the difference in the character of the strata from those of the underlying Coal Measures, although not great, is conveniently distinguishable. Still, it is true that the Texan Permian strata bear many Coal Measure invertebrate species, and its flora is at present unknown." *Medlicottia copei*, *Ptychites cumminsi* and *Popanoceras walcotti* are described and figured in this paper. They are characteristic Permian fossils.

In 1891 White republished the fauna just referred to, with descriptions of all the species, and giving four plates of illustrations. The discussion is much the same as was given in the former paper, with some additions, and a general section figured on page 14.[16] The list as revised is as follows: *Goniatites baylorensis* White, *Waagenoceras cumminsi* White, *Medlicottia copei* White, *Popanoceras walcotti* White, *Orthoceras rushensis* McChes.?, *Nautilus winslowi* Meek and Worthen, *Nautilus occidentalis* Swallow, three undetermined species of *Nautilus*, *N.* (*Endolobus*)—?, *Naticopsis remex* White, *N. shumardi* McChes.?, *Euomphalus subquadratus* Meek and Worthen, *E.* ——?, *Murchisonia* ——?, *Patella* ——?, *Bellerophon*

16. Bull. 77, U. S. Geol. Surv., 1891.

crassus Meek and Worthen, *B. montfortianus* Norwood and Pratten, *B.* ——?, *Sedgwickia topekaensis* Shumard, *Pleurophorus* ——?, *Clidophorus occidentalis* Geinitz, *Yoldia? subscitula* Meek and Hayden, *Myalina permiana* Swallow, *Myalina aviculoides* Meek and Hayden, *M. perattenuata* Meek and Hayden, *Gervillia longa* Geinitz, *Aviculopecten occidentalis* Shumard, *Syringopora* ——?, *Spirorbis* ——?, *Cythere nebrascensis* Geinitz.

On page 113 in the former paper and on page 13 of this one, White states, concerning the upper limit of the Texas Permian, that "Along the western boundary of the Texan Permian, as it has been characterized in the preceding paragraphs, a series of strata about 250 feet in maximum thickness, now generally known as the gypsum-bearing beds and thought by some geologists to be of Triassic age, rest conformably upon the Permian. In general aspect, in a prevailing reddish color, and in general lithological character, except the prevalence of gypsum in some of the layers, and the somewhat greater prevalence of clayey material, these overlying beds resemble the Permian beds upon which they rest. With only one known exception, these gypsum-bearing beds have furnished no fossils. The exception referred to is the discovery by Mr. Cummins in Hardeman county, in the upper stratum of those beds, of a thin magnesian layer, containing numerous casts of a species of *Pleurophorus*. This being generally regarded as a characteristic genus among Permian molluscan faunas, and also being a prevailing form in the Permian strata beneath these gypsum-bearing beds, the question is suggested whether the latter ought not to be regarded as constituting an upper part of the Texan Permian. These beds have yet furnished no fossils which can with propriety be referred to the Trias, and it is questionable whether any Triassic strata exist in Texas."

In an article entitled "Report on the Geology of Northwestern Texas," Prof. W. F. Cummins gives a resume of the previous papers on the Permian and other formations of that region,[17] some of which have been referred to above. His discussion of the Permian is rather full,[18] giving twenty-four

17. Sec. Ann. Rep. Geol. Tex., pp. 359-553, 1901.

18. Pages 394-424.

detailed sections and describes the stratigraphy and paleontology. In his introductory sentence to the subject Permian, he says that "It is intended to include in the Permian all the Red Beds in Texas which lie between the upper part of the Albany beds of the Coal Measures and the Dockum beds, or the lower part of the Triassic as recognized here." He thus definitely limits the horizon of the Texan Permian. "That there is a hiatus between these two formations (Trias and Coal Measures) as defined in North America, is a well-known fact. By evidence that will be given hereafter I wish to show that the series of strata that I here call Permian is different from either the Triassic above or the Carboniferous below, as they have been formerly identified." He points out the conformability of the Red Beds and the Coal Measures and the striking unconformity separating them from the Dockum beds or Triassic. In discussing the thickness of these beds, he says: "For quite a while it was thought that the Permian was merely the rounding off of the great Paleozoic area, and that it would only be found in narrow strips along the edge of the Carboniferous formation, but such can no longer be said to be the case, for the Permian has been found in the United States extending over a vast region and is more than 2000 feet thick. In Texas the whole of the beds placed in the Permian are at least 5000 feet thick. These beds must have required a long period of time for their deposition, and the formation is entitled to be represented as a series in geological nomenclature."

He divides these beds into three divisions in ascending order: The Wichita, Clear Fork and Double Mountain beds. The Wichita beds are characterized as consisting of "sandstones, clay beds, and a peculiar conglomerate." There is an absence of limestones. The Clear Fork beds are characterized as limestones, clay and shale beds, and sandstones. The Double Mountain beds are composed of sandstones, limestones, sandy shales, red and bluish clays, and thick beds of gypsum. Sections in the three formations are given and the details of stratigraphy entered into. He states that the Double Mountain beds "lie directly in contact with the Clear Fork beds throughout the whole length, and no at-

tempt has been made to determine a definite line of division between the two divisions.

"Doctor White, . . . described the invertebrate fossils taken from the Wichita beds and the lower part of the Clear Fork beds. . . . Prof. E. D. Cope has described the vertebrate fossils from the Permian beds of Texas, . . . collected from the same beds as those from which the invertebrates were taken that were described by Doctor White, some of them a little higher in the series."[19]

It is thus clear that the lower Red Beds were clearly established as Permian by Cope, White and Cummins at an early date and the limits established, based on paleontological evidence. In the following part of the discussion of the Permian, Cummins takes up Hay's paper[20] and discusses his theses, or reasons, for referring the Red Beds to the Jura-Trias. A significant remark of Cummins's concerning the correlation of the Kansas beds with those of Texas is that he has traveled as far north as the Canadian river north of Mobeetie, and down the river opposite the lower end of the Wichita mountains, and "seen only the Double Mountain beds. The older beds of the Permian may have been exposed farther northward in Kansas, but I am of the opinion that southwestern Kansas has only the uppermost beds, which Mr. Hay has synchronized with strata near the mouth of the North Fork of Red river. This I judge from Mr. Hay's description of the strata." This is Mr. Cummins's conclusion of the matter, while Hay argued that they were Jura-Trias. On page 408 Cummins states, under the head, "Double Mountain beds": "The fossils recognized [in section No. 19] were two species of ammonite, *Orthoceras* and *Pleurophorus*. The upper part of No. 2 of the above section was almost entirely composed of ammonites."

On page 222 of the fourth annual report, after discussing the correlation of the Texas Permian, he states that "it is still too early to attempt exact correlation, but it is quite probable that the Albany division of the Coal Measures will prove the same as the beds at Fort Riley, Kan.

19. Ibid., pp. 413, 414.

20. Bull. 57, U. S. Geol. Surv., 1890, pp. 23-25.

"Prof. A. Hyatt has published a figure of *Phacoceras dumblei*. This fossil was taken from the very top of the Albany division in Texas. It was also found at Fort Riley, in Kansas; and as the form is supposed to have but a short range in time, it would go far to assist in correlating the strata."

In the light of later work by Adams, to be referred to below, the statement made on page 223 of this paper is of extreme interest; the italics are mine: "North of the Brazos river the Wichita division of the Permian rests directly on the Cisco division of the Coal Measures. In a word, it occupies the same position, stratigraphically, as the Albany division on the south. *It may be that the Wichita and Albany divisions are but different facies of the same formation.* The question will have to be determined by a close study of the stratigraphy."

"If it shall be finally determined that the *Wichita and Albany divisions are but different facies of the same formation, it will at once settle the question of boundary between the Carboniferous and Permian in North America, for there is no dispute about the Wichita beds being Permian.*"

He also states that the fossil flora from the Permian described by Profs. I. C. White and Fontaine were taken from the Wichita division, and that "the flora collected bears out the conclusion that has been so far clearly shown by the vertebrate and invertebrate fossils, that the strata from which it was taken are Permian." He then discusses the Clear Fork division, and states that it probably extends north into Kansas. He then takes up the discussion of the Double Mountain beds. Concerning the age of these, the gypsum-bearing beds, he says: "During the past season's field-work I have traveled across the Permian area twice, and have collections of fossils from several localities in both the Clear Fork and Double Mountain divisions. I have found no fossils higher than the locality already mentioned as the falls of Salt Croton creek, which is within less than 300 feet of the top of the division. As a necessary result, if the beds at the falls on Salt Croton creek can be shown to be Permian, then there can be no dispute as to the beds situated between that and the Wichita being Permian also."

The fossils found by him in the Double Mountain beds are

mentioned, as follows: "The fossils from the Double Mountain division were collected at several places. The principal localities were Guthrie, in King county, and the falls on Salt Croton, in Kent county. They are both towards the top of the division. The fossils found are species of *Medlicottia*, *Popanoceras*, *Orthoceras*, *Pleurophorus*, *Goniatites*, *Schizodus*, and others which have not been determined. The finding of these forms at these localities will certainly establish the Permian age of the beds. The *Medlicottia* found in the Double Mountain beds is the form described by Doctor White from the Wichita division, and not the *Sagerceras* described by Gabb from the Triassic of Nevada. The last reason for putting the Double Mountain division in the Permian is, that immediately above, and in unconformable stratification, are beds beyond doubt Triassic."

In a paper read before the Texas Academy of Science in 1897[21] Cummins gives a resume of the detailed work of the latter portion of the Texas survey, which is of so great interest that it is necessary to repeat some of it here. As quoted above, he had divided the Permian rocks into three divisions, and the Coal Measures had been divided into five, "for facility in giving particular descriptions of the different beds. It was understood at the time that these divisions were made that they were provisional, and subject to revision when their true relationship to each other might be determined." After discussing the statements made repeatedly in the Texas reports that the Wichita and Albany divisions occupied about the same position stratigraphically, and the statements quoted above, that they might be but different facies of the same formation, he states that "*by walking along the outcrop every foot of the way we were enabled to note the gradual change in the lithological character of the bed.*[22] We were also enabled to note the gradual extinction and change in the fossils as the beds changed in composition.

"We found that a limestone in the Albany division with an abundant and characteristic Coal Measures fauna gradually changed in composition to a calcareous sandy clay entirely

21. Texas Permian, June 15, 1897, pp. 93-98.

22. Italics are mine.

destitute of fossils of any kind. Other limestone beds in the Albany division when traced northeastward would gradually pass into sandstone, while others would entirely disappear."

He then discusses in detail the gradual changes in lithological characters and the corresponding changes in the fauna, and states that by "thus tracing the escarpment between the two points, the Clear Fork of the Brazos river and the Big Wichita river, and finding it continuous, we demonstrated very clearly that the beds called the upper part of the Albany division in the previous reports are the same as those called the upper part of the Wichita division in the same reports."

After making these discoveries he includes the Albany division in the Wichita, calling it all Wichita, as they are synchronous. He closes the paper by correlating the basal Permian of Kansas and Texas in this manner: "The *Phacoceras dumblei* Hyatt has been found only along a very narrow horizon in the Texas Permian. That horizon was traced and the fossils found for a distance of seventy-five miles. The fossil was found quite numerous at places, so that it might be said that the bed was characterized by that fossil. This fact will assist materially in correlating the Texas and Kansas beds, as that fossil has been reported only from one locality in the Kansas area, where it is associated with the same fossils as in Texas. It is quite certain that the Fort Riley horizon is the same as the Wichita division in Texas, and is at the very top of the division. . . ."

In 1892 Dumble and Cummins visited the Double mountains and made a careful section of the rocks there, which may, perhaps, be taken as typical of the summit of the southern Red Beds and their relation to the Triassic. The Double Mountain section is as follows:[23]

			Feet.
Lower Cretaceous.	1.	Caprina limestone	40
	2.	Comanche Peak series	55
	3.	Trinity	25
Trias	3*a*.	Dockum	35
Permian	4.	Shaly clay, underlaid by red or terra-cotta sandstone,	105
	5.	Upper gypsum beds	60
	6.	Middle gypsum beds	75
	7.	Lower gypsum beds	135

Concerning the relation of the Dockum beds of the Triassic

23. Dumble and Cummins, Amer. Geol., IX, pp. 347-351, June, 1892.

to the underlying Double Mountain beds of this section, they say: "Underlying the conglomerate last mentioned (Dockum beds), but separated by a bold unconformity, we find five feet of sandy clay dipping toward the northwest. It is underlaid by a red or terra-cotta sandstone, somewhat mixed with clay toward the top and bedded in layers which vary in thickness from one foot to an inch or less. There are two seams of impure limestone embedded in the sand, but although a careful search was made for fossils none were found.

"The red or terra-cotta sandstone rests directly upon the upper gypsum beds, which consist of an upper layer of gypsum underlaid by yellow and red sandy clays or shales which are much cross-bedded. Gypsum also occurs throughout the clays."

This is followed by a brief description of the remaining gypsum beds. No fossils were found in the Triassic or Permian beds at this place.

In the Second Annual Report of the Texas Survey[24] N. F. Drake describes the area and stratigraphy of the Dockum beds overlying the Permian in western Texas. In this paper he graphically describes the unconformity between the Triassic and Permian beds, and brings out the fact that the Dockum beds are fresh-water deposits, as instanced by the *Unio* invertebrate fauna and the shallow-water vertebrate fauna described by Cope in the article following Drake's.

The foregoing quotations are sufficiently complete to require but little comment here. They demonstrate the thoroughness with which the Texas survey worked out the geology of these deposits, and, as will be shown later, they correspond well with the more recent work to the northward.

In 1892 Tarr published an article on the Texas Permian[25] in which he discusses the general syncline in which the southern part of the Red Beds lie. His conclusion is that the Red Beds were laid down in an inland sea. He says that "the Permian conditions are, therefore, foreshadowed in the Carboniferous, and probably, also, the conditions which culminated in Permian times in the completely enclosed dead

24. Pages 227-247, 1892.

25. Amer. Jour. Sci., XLIII, pp. 9-12, 1892.

sea were in Coleman times [Upper Pennsylvanian] indicated by the gathering in of shore-lines and the partial enclosure of a mediterranean sea. . . . In summary it may be said that the object of this paper is to show that the Permian of Texas is, like other areas of the Permian, such as those of Europe, a deposit in large measure made in an inland sea, at certain times in its history a dead sea. . . ."

To a large extent I agree with these statements, though it will have to be understood that this inland sea was open somewhere occasionally to admit the foreign elements of the fauna which appear in the lower part, as well as that of the Whitehorse sandstone and the Quartermaster beds, at two distinct periods in its late history. Similar opinions have been expressed by others in accounting for these beds.

This brings the discussion of the Texas beds down to the last few years. I have not cited all the papers written on this subject in the preceding pages. However, I have endeavored to discuss much of the more important material bearing on the Texas Permian, confining myself largely to the work of those who have made the most careful and extended observations in the field and who have contributed the most evidence bearing on the age of these beds. Some of the statements quoted will be discussed in the light of later knowledge, in the proper place.

While the explorations were being carried on in Texas the Kansas geologists were endeavoring to solve the same problems in Kansas. This work has been so thoroughly summarized by Prosser[26] that it will be unnecessary to give it here. On account of differences in lithologic characters between the Red Beds of Texas and Kansas and the unexplored region of great extent lying between them, it was impossible to determine the age of the Kansas beds without fossils, which have been, so far, lacking. This region had been hurriedly crossed by Cope, who was inclined to the opinion that the Kansas beds and those of Indian Territory [now Oklahoma] were Permian, yet he was not certain enough of it to make the declaration without reservation.

Within the last decade much light has been thrown on this

26. Univ. Geol. Surv. Kan., II, pp. 55-95 1897.

subject, with the result that the age of the Kansas and Oklahoma beds is pretty well understood. Cragin, Gould, Adams and Kirk are the ones to whom we are principally indebted for the field-work, and Williston and Case for the determination of the vertebrates. My knowledge of the stratigraphy of the Red Beds of Oklahoma is too limited to enter into a detailed discussion of the merits and value and synonomy of the various formational names proposed for the horizons of Kansas and Oklahoma, and I will content myself with keeping track of the larger divisions only, which, in the main, concern us here.

In 1897 Prof. F. W. Cragin published an article entitled "Observations on the Cimarron Series,"[27] in which he gives the results of a trip across the territory of Oklahoma. In this paper he shows that the horizon of the large gypsum beds extends into southern Oklahoma and Texas. Cragin here refers all the Kansas Red Beds to the Permian, on stratigraphic evidence, which, however, is much stronger than that upon which most of the previous opinions concerning the age of these beds was based. The bulk of the paper is concerned in the minutiæ of the stratigraphy of these beds and a revision of their classification.

In 1898 Adams made a trip into Oklahoma from southern Kansas, and gives a brief description of the trip and its results in an article in the *Kansas University Quarterly*.[28] He describes the appearance and features of the Red Beds in three counties, including the Glass mountains. He gives a reconnaissance map of the region.

Gould published a statement showing the change of the Wellington shales into red strata, near Vardin, Okla.[29]

In 1900 Gould, with two other members of the Oklahoma survey, made an extended trip into the northeastern part of the territory,[30] for the purpose of determining the nature of the Upper Pennsylvanian and Lower Permian of that region. In the article mentioned he shows how the limestones and

27. Amer. Geol., XIX, pp. 351-363, 1897.

28. A Geological Reconnaissance in Grant, Garfield and Woods Counties, Oklahoma. Kan. Univ. Quart., VII, pp. 121-124, 1898.

29. Kan. Univ. Quart., 1900, pp. 175-177.

30. Notes on the Geology of Parts of the Seminole, Creek, Cherokee and Osage Nations. Amer. Jour. Sci., XI, pp. 185-190, 1901.

shales of the top of the Pennsylvanian and the Wreford limestone and associated formations finally give place to reddish sandstones and shales similar to those of the Red Beds above, just as Cummins had shown them to do in Texas on passing northward. He sums up the results of the trip as follows: "1. The Flint Hills do not extend as far south as the Seminole country. 2. The sandstone which is well developed in the eastern part of Chautauqua county, Kansas, continues uninterruptedly southward east of the Flint Hills, beyond the North Canadian river. 3. The eastern limit of the Red Beds in southern Oklahoma is not far from the western part of the Seminole country. . . ."

Adams made a trip in this region and east of it, coming to much the same conclusion as Gould, but giving a map illustrating the change in color and lithology of the formations.[31] In this paper Adams states that the sections of Gould and Drake were taken as cross-sections of the rocks and did not permit of accurate correlation. While some of Gould's sections were taken at points where the correlation was uncertain, yet this criticism probably was not intended to apply to Gould's paper as a whole, for the stratigraphy of the northern region bears the evidence of being correct, and the horizons of the upper part properly correlated, and, furthermore, it corresponds with Adams's correlations as shown on his map.

In another place[32] Gould describes how the Marion and Wellington formations change from light-colored calcareous and argillaceous beds to more arenaceous red sediments like the overlying Red Beds. These accounts of his give us a very fair idea of the lithologic changes taking place in the southern extension of the Kansas Lower Permian. He describes the passage of the Gypsum Hills from Kansas into Texas, the result of his work on the Oklahoma survey in the same year,[33] showing that the upper Red Beds are the same in the three states.

Adams published articles in *Science* and the *Bulletin of the*

31. Carboniferous and Permian Age of the Red Beds. Amer. Jour. Sci., XII, pp. 383-386, 1901.

32. On the Southern Extension of the Marion and Wellington Formations. Trans. Kan. Acad. Sci., XVII, pp. 179-181, 1901.

33. Amer. Geol., XXVII, pp. 188-190, 1901.

Geological Society of America, concerning preliminary studies in Texas[34] on the relationship of the Red Beds to the limestones and shales to the southward. He states his reconnaissance work confirms the detailed work of Cummins in showing the Albany and Wichita beds to be different facies of the same horizon as quoted above. On page 198 of the last reference cited, under the caption "obsolete terms," Adams states: "Concerning the terms Wichita, Clear Fork, and Double Mountain, it may be said that there is little reason to believe that they should be any longer retained, since they have no stratigraphic significance." The retention of these terms is a necessity until, by further work, it can be shown that a better general classification is available. Had any detailed work been done showing the necessity of any changes in formation names, or showing any inaccuracy in the later detailed work of Cummins, the situation would be very different.

Four publications have added an inestimable amount to our knowledge of the geology of Oklahoma and the Panhandle of Texas. The first of these is the Second Biennial Report of the Department of Geology and Natural History of the Territory of Oklahoma. In it are two articles bearing on the subject under consideration. The first of these is the "General Geology of Oklahoma," by Gould.[35] In this paper he gives a brief review of previous literature and then describes in fair detail the geology of the territory. He discusses the manner in which the lighter deposits to the north dissipate into red deposits of the territory, agreeing with Adams that the eastern extremity of these beds are Pennsylvanian. He then gives the classification of Cragin, and shows how it is necessary to revise it on account of conditions found in Oklahoma which are not exhibited in the northern extremity of the formations in Kansas. His section is given below. He gives Cragin's classification and his own modified to meet

34. Sci., XV, pp. 545, 546; XVI, p. 1029, 1902. Bull. Geol. Soc. Amer., XIV, pp. 191-200, 1903.

35. Pages 17-74, 1902.

the knowledge of the Oklahoma deposits at that time.[36] The table follows:

Cragin's classification.		Classification used in this report.
	QUARTERMASTER DIVISION.	——— ———
Big Basin sandstone. Hackberry shales.	GREER DIVISION.	Delphi dolomite. Collingsworth gypsum. Cedartop gypsum. Haystack gypsum. Kiser gypsum. Chaney gypsum.
Day Creek dolomite. Red Bluff sandstones. Dog Creek shales.	WOODWARD DIVISION.	Day Creek dolomite. Red Bluff sandstones. Dog Creek shales.
Cave Creek gypsums. Flower-pot shales, upper part.	BLAINE DIVISION.	Shimer gypsums. Altoona dolomite. Medicine Lodge gypsum. Magpie dolomite. Ferguson gypsum.
Flower-pot shales, lower part. Cedar Hill sandstones. Salt Plain measures. Harper sandstones.	NORMAN DIVISION.	——— ——— ——— ———

"The term 'division' is here used in a general sense, corresponding with its ordinary English meaning, to designate a larger or smaller sequence of strata which may in one instance correspond to a formation having a simple and uniform lithologic character, or in another to a group of such formations."

In discussing the Norman division, which is not differentiated in the section, he states that "the rocks of the Norman division consist chiefly of brick-red clay shales, with some interbedded ledges of red and white sandstone. In the eastern part of its visible extent sandstone predominates, while in the region along the base of the Gypsum Hills the beds consist almost wholly of clay.

"The Norman division may be divided on lithological grounds into three general districts, as follows: An eastern district, in which the sandstones are of sufficient thickness to form prominent ledges; a central district, in which the sandstones are thinner and consequently less conspicuous; and a western district, in which the sandstones are practically wanting. It is impossible, in the present state of our knowl-

36. Loc. cit., p. 42.

edge, to draw lines of separation accurately between these districts, and for this reason the strata are not herein defined and named as separate formations."

The remainder of the divisions are sufficiently subdivided for our purposes as given in the above table. Each of the subdivisions is described and their extent indicated in the text. Following the part on geology is an extensive report on the gypsum of Oklahoma, containing many points of interest to the stratigrapher, especially since the gypsum beds form the principal relief of the upper Red Beds. In the geological part of the report the paleontology of the territory is discussed, and will be referred to later.

The second of the four papers is the third biennial report of the same survey. I have already reviewed this report,[37] and will merely call attention to the point of interest to us here. Kirk traced the Wreford limestone of Kansas, and the sandstone (Payne) into which it dissipates, from southern Kansas to the vicinity of Norman. It will be seen that the strike of it is such as to pass around the east side of the Wichita mountains, if traceable all the way, and arrive near the outcrop of the Wichita formation of Texas. It is a matter of considerable importance and it is to be hoped that the Oklahoma geologists will soon be able to trace it out, as it would form an unimpeachable connecting link between the Kansas and Texas Permian. This sandstone lies in the lower part of the Norman division.

The third of these papers is the "Geology and Water Resources of Oklahoma and the Eastern Panhandle of Texas."[38] In this paper we have the first geological map of the territory, accompanied by a discussion of the formations represented, which seem to be worked out with considerable care for a reconnaissance map, and add greatly to our knowledge of the region. The manner of the gradation of the Kansas light Permian into the red shales and sandstones is shown on this map, the gradual replacement taking place soon after crossing the boundary line.

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37. Amer. Geol., XXXV, p. 390, 1905.

38. U. S. Water-supp. and Irr. Pap., 154, 1906.

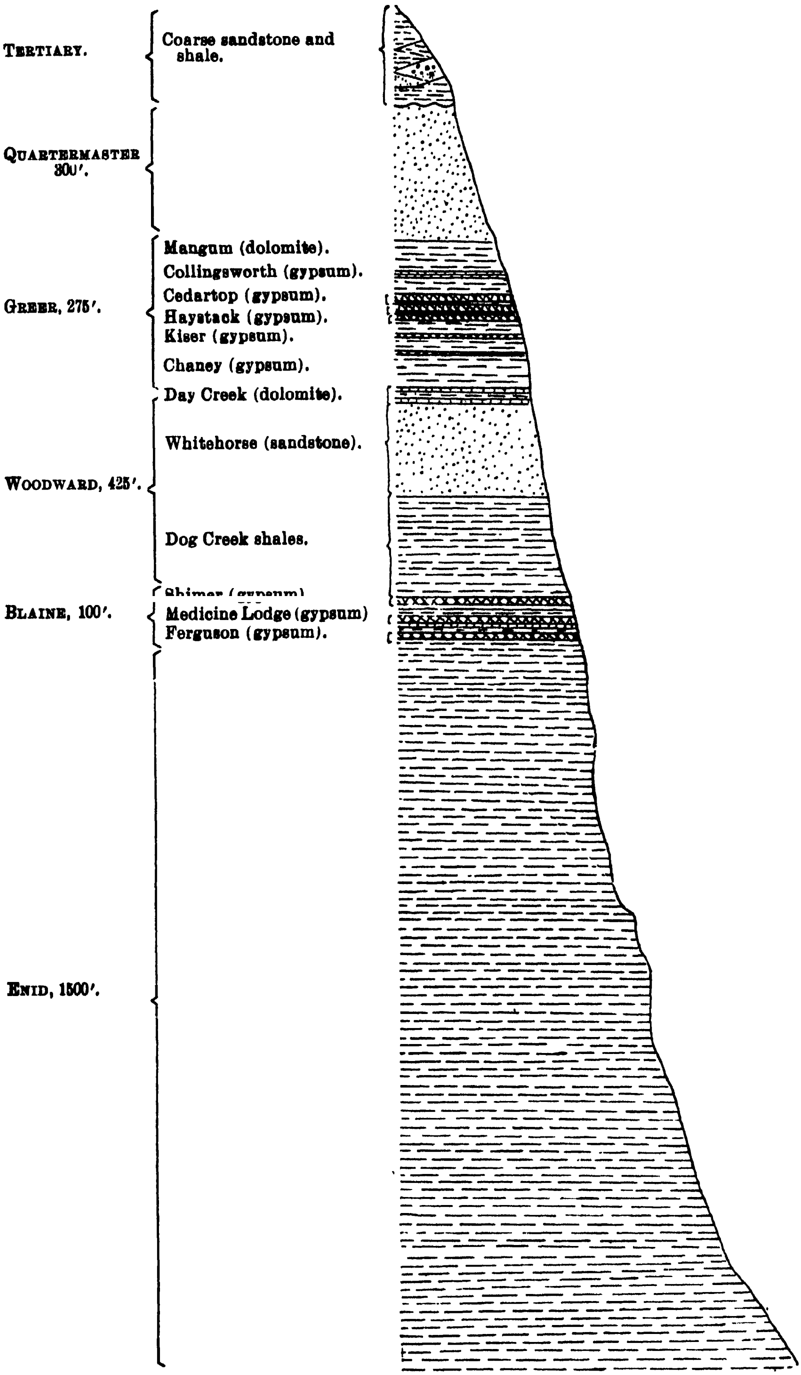

FIG. 1.—General section of the rocks of Oklahoma. Redrawn after Gould.

There are a few changes in the classification used in this paper from the preceding ones. In the present classification it is seen that the gypsum beds and the groups of gypsum beds, which form the salient topographic features of the country, play an important part. They are separated by successions of sandstones and shales and dolomites. It will be seen from the above cut that Gould has replaced the term "Norman" with "Enid," limiting it thus: "The Enid formation includes all the rocks of the Red Beds from the base of the Permian to the lowermost of the gypsum ledges on the eastern slope of the Gypsum Hills. The top of this formation, however, is not a plane, since the gypsum beds which mark its topmost limits are found to be more or less lenticular when traced for long distances. The Enid comprises all of the Harper, Salt Plains and Cedar Hills members of Cragin's first paper, and the Kingfisher and Glass Mountain formations of his second paper. It is named from the county-seat of Garfield county."

It will be seen that the Enid differs from the Norman as previously defined in excluding the rocks referred to the Red Beds which are the equivalents of the Pennsylvanian rocks below the Permian; hence, probably, the reason for substituting the second term. The general section gives an adequate idea of the stratigraphic succession and the groupings. The invertebrate fossils mentioned in this paper were taken from the Whitehorse sandstone and the upper part of the Quartermaster division.

In the "Geology and Water Resources of the Eastern Panhandle of Texas," Gould carries the mapping west to the foot of the Staked Plains and discovers the Dockum beds lying unconformably upon the top of the Quartermaster formation,[39] but pinching out to the north and not extending into Kansas. Neither are they represented in Oklahoma.

The Dockum beds may extend, in local patches beneath the later rocks, into southwestern Kansas, but are not exposed at the surface.

Perhaps the first article to appear on the vertebrate paleontology of Oklahoma was by Williston, entitled "Notes on the

39. U. S. Water-supp. and Irr. Pap., 154, 1906.

Coracoscapula of *Eryops* Cope,"[40] which was taken from the Enid division, the part probably corresponding to the Wellington formation, as pointed out by Gould. T. Rupert Jones had previously referred the species of crustacean found with the bones at the McCann quarry provisionally to *Estheria? minuta*, abundant in the Triassic system. However, it is only fair to say that the material was so poor that no positive determination could be made. In the discussion of the paleontology of the Red Beds, Gould gives a list of fossils from Orlando from about the same part of the Enid beds.[41] They are *Diplocaulus magnicornus* Cope, Diadectidæ, Gen. Indt., *Pariotichus incisivus?* Cope, labyrinthodont, *Trimerorhachis*. This list was furnished by Doctor Williston as a preliminary one. Concerning it he says: "*Diplocaulus* is an amphibian. The genus occurs in the Permian of Illinois and Texas, according to Cope. The Diadectidæ is a family of theromorph or theriodont reptiles, known only from the Permian of Texas. *Pariotichus incisivus* Cope, from the Permian of Texas, belongs to a family closely allied to the Diadectidæ. *Trimerorhachis* is a genus of stegocephs, from the Permian of Texas.

"All together, you see that these fossils point unmistakably to the Permian. . . ."

Case, in the same paper[42] gives a list and descriptions of fossils occurring at the Orlando locality and makes the following comment: "The collection is of especial interest as it shows a close relationship, both in its forms and its manner of fossilization, to the deposits of northern Texas. Still more interesting is the discovery of forms having the same character of neural and hæmal spines as are found in the forms from the Carboniferous of Linton, Ohio, and in the Permian deposits of Ireland and Bohemia. Two or three forms, as *Trimerorhachis* and *Diplocaulus*, are common to this region and the deposits of Illinois, but the fauna is much more closely related, as is to be expected, with that of the Texas Permian. It is perhaps worthy of note that there is a notice-

40. Kan. Univ. Quart., VIII, pp. 185, 186, pll. XXVI, XXIX, XXX, 1899.

41. Sec. Bienn. Rep. Oklahoma Dept. Geol. and Nat. Hist., p. 60, 1902.

42. Ibid., p. 62.

able difference in the fauna of Illinois and Oklahoma and Texas." Following is the list as given by Case: *Sagenodus?* sp., *Diplocaulus magnicornis?* Cope, *Diplocaulus limbatus?* Cope, *Diplocaulus salamandroides* Cope, *Trimerorhachis* sp. Cope, *Trimerorhachis leptorhynchus* Case, *Cricotus* sp., *Cricotillis brachydens* Case, *Eryops megacephalus* Cope, *Crossotelos annulata* Case, *Naosaurus* sp., *Embolophorus?* sp., *Pariotichus ordinatus* Cope, *Pariotichus* sp., *Pleuristion brachycœlus* Case, *Diacranodus* (*Pleuracanthus*) *compressus?*. According to Cope, Williston, and Case, these fossils demonstrate unmistakably the Permian age of the strata from which they were taken. Case states, after having described the vertebrates from the base of over 2000 feet of the strata, that "the result of the determination of these fossils has been to settle the long-mooted question of the age of the Red Beds."[43]

A remark concerning the horizon of some vertebrates described from the Kansas strata is to the point here. Williston described a specimen from Cowley county, Kansas,[44] in 1897, which he states "clearly belongs to the genus *Cricotus*, and is closely allied to the typical species described by Cope from the Permian of Illinois. His description applies so well to the specimen in hand that I use his language, amended." "A single dorsal vertebra, and, perhaps, some phalanges, belong clearly to the genus *Clepsydrops* Cope, as originally described from Illinois. . . . Associated with these remains are numerous teeth and spines of *Pleuracanthus* (*Didymodus?*) and the plates of a ganoid fish.

"All together, we have here an interesting series of forms, so closely resembling the species described by Cope from Danville, Ill., that I cannot distinguish them specifically. It would seem to demonstrate the contemporaneity of the two formations, and also that of the Texas Permian, whence the species of all these genera have been described by Cope."

These bones were taken from the Garrison formation, south of Dexter, Kan., about fifty feet below the base of the Wreford limestone, which is taken as the base of the Permian by the Kansas geologists. Another very interesting discovery

43. Op. cit., p. 68.

44. Trans. Kan. Acad. Sci., XV, pp. 120-122, 1898.

is brought to light by Doctor Williston in the description of labyrinthodont remains which seem to belong to a genus not heretofore known below the Triassic, from a horizon about 200 feet below the horizon of the Dexter bones, in southern Pottawatomie county, Kansas.[45] These remains were provisionally referred to the genus *Mastodonosaurus*.

These vertebrates are considered to be quite as ephemeral as any invertebrate species, and equally good, for that reason, for purposes of correlation. In the light of these facts, it would seem that the base of the Wichita division of Texas might be somewhere in the neighborhood of the horizon of the Garrison formation of Kansas. This has an interesting bearing on the location of the line of division between the Pennsylvanian and Permian of Kansas, and, together with published data on the plants and the known invertebrate fauna, go to demonstrate that the base of the Permian has not been placed too high by the Kansas geologists in using the Wreford limestone as its lowermost formation.

In April, 1902, the present writer published a note with the figures of some fossils from the Whitehorse sandstone, eighteen miles west of Alva, Okla. The species mentioned were *Bakewellia* (referred provisionally to *Cyrtodontarca*) *gouldii*, *Conocardium oklahomaensis*, *Aviculopecten vanvleeti*, *Naticopsis* sp., *Pleurotomaria* sp., *Dielasma schucherti*, and *Schizodus* sp. After a brief discussion of the fauna, the following statement is made: "Taking all this into consideration, there can be but little doubt that the age of these beds is Permian."

It is interesting to note that work in the Rocky Mountain region is showing similar results to those obtained near the foot of the high plains to the eastward. Cross and Howe have recently carefully described the unconformity between the Triassic Red Beds and the underlying beds, supposed to be the Permian, in Colorado. Drake described this unconformity to the west of the Llano Estacado, and Williston has discovered a rich Triassic vertebrate fauna from the upper Red Beds of Wyoming, while Knight showed that the lower portion of them were Permian. Herrick found Permian invertebrates in the lower Red Beds of New Mexico. These

45. Kan. Univ. Quart., VI, pp. 209, 210, 1897.

discoveries are of especial interest, giving us an idea of the great extent of the Permian sea in America.

SUMMARY.

The foregoing has shown the following facts to be ascertained to date. Cope, Cummins and White have demonstrated that the Wichita (including the Albany) and Clear Fork beds of Texas are unmistakably Permian.

Cummins showed, by mention of fossils, that the beds above to within about "300 feet" of the top of the Red Beds (below the Dockum beds) of Texas are Permian. This would be to about the horizon of the Whitehorse sandstone of Oklahoma.

Cragin and Gould have shown on stratigraphic grounds that the gypsum-bearing beds of Kansas, Oklahoma and Texas are, in a general way, equivalent.

Cummins, Adams and Gould have demonstrated that the light-colored Permian rocks of Kansas and Texas have their equivalents in the red strata of Oklahoma.

Williston and Case have demonstrated that the lower Enid formation of Oklahoma is Permian and of similar horizon to some parts of the Wichita and Clear Fork divisions of Texas.

Beede has shown that the beds as high as the Whitehorse sandstone of Oklahoma are Permian.

Gould has shown that the Whitehorse sandstone is identical with Cragin's Red Bluff formation of Kansas.

FAUNA OF THE WHITEHORSE AND QUARTERMASTER SANDSTONES.

In the present paper the fauna of the Quartermaster division is added to that of the Whitehorse sandstone. As Gould has pointed out, the Quartermaster division is the highest formation in the Red Beds, and the fossils came from well up in this formation.

The fauna of the Quartermaster beds is different in some respects from that of the Whitehorse sandstone, several new elements having been introduced. The literature at hand is unsatisfactory concerning three species of the gastropods of this formation, notably *Naticella*. In order that no possibility of mistake be made, the types of the whole Quarter-

master fauna, as here illustrated, were sent Mr. T. W. Stanton, who stated that they were unmistakably Paleozoic.

It was unfortunate that the entire type collection (except two specimens) of the Whitehorse sandstone as figured in the first bulletin of the Oklahoma survey was destroyed in the fire which consumed Science hall at the University of Oklahoma. In order that there might be specimens for comparison as near the types as possible, and collected from the type locality, I have figured here a new set, which are now in the museum of the University of Kansas.

The fossils upon which this paper is based were collected by the writer in the summer of 1904. Those from the Whitehorse sandstone were taken from Whitehorse spring, some two miles or more southeast of Whitehorse post-office, and eighteen miles due west of Alva, Okla. They were taken from the top of the hill just west of the spring. Those from the Quartermaster division are from the sandstone rolled down on the west side of the "Dozier mountains," east of Mr. Caperton's place (then the Dozier post-office), fifteen miles south or southwest of Shamrock, in the Panhandle of Texas.

The faunas are somewhat heterogeneous as to origin. Some of the species seem to be directly derived from the Kansas Permian or Pennsylvanian, while others, as pointed out in the discussion of the species, are derived from the European Permian, especially that of Russia. There seems to be comparatively little resemblance to the Indian or Chinese forms. The fossils described as *Dielasma schucherti* Beede seem to have their closest allies in the Productus limestone of India, the only species, perhaps, with pronounced Indian affinities.

The following fossils have decided American affinities and may be the progeny of the fossils of the older rocks of the western Mississippi valley. These species are: *Pseudomonotis*, *Solenomya*, two species of *Edmondia* (perhaps), *Myalina*, *Schizodus* (two species), *Aviculopecten* (two species), *Pleurophorus*, *Pleurotomaria agnostica*, *Trepospira haworthi* (has affinities both in American and in Kulogory, Russia), *Loxonema*, *Orthonema* (two species), *Bulimorpha*, and *Strophostylus permianus*. Those of foreign affinities are: The *Cyrto-*

dontarcas, both foreign and American, but probably more closely related to the American forms, *Pleurotomaria capertoni* (Oka-Kljsama or England), *Worthenopsis depressa* (England), and Oka-Kljasma Becken, *Murchisonia collingsworthensis* (Donnez basin), *Naticella transversa*, to the Carboniferous of Belgium and the Urals and Triassic of St. Cassian. It is to be held in mind that these affinities may be largely superficial, as the preservation of the specimens is such as to obliterate many of the critical characters. However, a comparison of plate IV of Jakowlew's paper on the "Fauna Einiger Oberpalæozoischer Ablagerungen Russlands" with the last plate of this article can not fail to impress one with the similarity in general aspect.

The gastropods of the Dozier beds appear to have their closest foreign affinities with the Upper Permo-Carboniferous and Lower Permian faunas of the Oka-Kljasma Becken and Kulogory of Russia, as shown by Jakowlew in the paper cited above. The pelecypods seem closely related to the fauna of the Donnez basin. *Cyrtodontarca*, described by Jakowlew, is not identical with any of the American species, being more robust and having a slightly different type of dentition. It is perhaps more closely related to *C. gouldii*, or *C. multidentata*, than to the other species.

This Russian fauna is from a much older horizon than the species described in this paper. It possesses such peculiar relationships that they deserve wider discussion than the scope of this paper permits, and will be taken up more fully in another paper now nearly ready for the press. It is composed of at least two distinct elements, one of which is very closely related to the Upper Pennsylvanian of Kansas and the Middle West, and containing several species in common, such as *Michelinia eugeneæ* White, *Lophophyllum profundum* Milne-Edwards and Haime, *Aviculopecten carboniferus* Stevens, *Entolium aviculatum* Swallow, *Pleurophorus oblongus* Meek, *Schizodus wheeleri* Swallow, *Edmondia aspenwallensis* Geinitz, and *Pleurophorus subcuneatus* Meek, a Lower Permian species of Kansas. Then there is *Cyrtodontarca bakewellhoides* Jakowlew, related to three species referred to this genus from the Whitehorse and Dozier sandstones, but specifically distinct from them.

The fact that none of the Russian species are identical with any of the Red Beds species and the identity of several of the Russian forms with the Pennsylvanian species found in the rocks below the Red Reds seems to argue a slow migration of the Upper Pennsylvanian fauna to the Russian provinces and a slower migration of the Lower, Middle and Upper Permo-Carboniferous and Lower Permian faunas to the Oklahoma-Texas region. The time lapse of the latter migration is represented by about 2000 feet of strata in the Red Beds region.

The concurrence of *Conocardium* in these rocks is almost anomalous. I know of but one other place where this genus is represented in the Permian, and that is a very different type of shell found in the province of Palermo, Sicily. The genus is, so far, unknown from the uppermost Pennsylvanian and lower Permian of Kansas.

The tabulation (page 146) gives the known species from the Red Beds. Those of the Enid formation of Oklahoma are placed in the same heading with the ones from the Wichita and Clear Fork of Texas. Careful detailed stratigraphic work will probably show that the Texas and Oklahoma fossil beds are not from exactly the same horizon as hinted at by Case.[46] However, they may be combined, if it is understood that it is merely to serve as a convenience here, and that the correlation is only intended in a general way.

Gould[47] interprets Adams's statements[48] concerning the identity of the Albany-Wichita beds as referring them to the Pennsylvanian. On the other hand, I am inclined to consider the statements as non-committal as to whether they are to be classed as Permian or Pennsylvanian. Cummins,[49] after demonstrating their identity, unhesitatingly referred them to the Permian. The paleontological evidence certainly bears him out in his conclusions.

In a letter from Professor Gould, under date of November 5, 1906, he gives additional and very good reasons for referring the Wichita-Albany beds to the Pennsylvanian. He

46. Loc. cit., p. 62.

47. Water-supp. and Irr. Pap., 154, p. 17.

48. Bull. Geol. Soc. Amer., XIV, pp. 191-200, 1903.

49. Tex. Acad., loc. cit.

states concerning the southwestward extension of the Wreford limestone (and Payne sandstone), previously mentioned, as traced out by Kirk, that "it crosses the South Canadian river at Purcell and is still trending southwest. If it continued, this would just about bring it in strike with the top of Cummins's so-called Wichita beds. The Red Beds of Oklahoma as far west as this line are probably Pennsylvanian." The last statement is based on paleontologic evidence.

If the horizon of the Wreford limestone should correspond to the upper Wichita, it would make the Kansas vertebrates described by Williston of similar horizon with the same fossils from Texas. It would agree very well also with the discovery of a Permian flora in Kansas below the Wreford limestone.

However, whether the Wichita beds are below or above the Wreford limestone, they must, it seems to me, be considered as Permian on paleontological evidence of great weight. In event the Wreford limestone should prove to be in the horizon of the upper Wichita division, the fact that *Phacoceras dumblei* Hiatt would then occur in a much higher horizon in Kansas than in Texas might be explained by the difficulty this clear water (limestone) species would have in getting through the muddy, irony waters of the intervening region, now occupied by red clays and sandstones. However, this must be regarded as pure speculation until our knowledge of the stratigraphic relationship of the two regions is much more complete.

It is necessary to say a word here regarding what are frequently mentioned as "Coal Measures species" and "Pennsylvanian species" in the Permian. They almost invariably refer to certain vigorous forms of great stratigraphic range, such as *Productus semireticulatus*, *Seminula argentia* and several others. Such cases are parallels, though with more restricted range, with *Leptæna rhomboidalis*, *Atrypa reticularis*, and others of the older rocks. When species of this character occur in the Permian rocks they deserve no more consideration than the occurrence of the latter two species when they occur anywhere within their known range. If we apply the laws of evolution to cases where continual sedimenta-

tion takes place through great lengths of time, we should expect to find faunal changes very gradual, especially in a nearly isolated epicontinental sea, though it be of great dimensions.

There seems to be little reason, therefore, for considering all sediments laid down in unbroken succession in a given region as belonging to the same period, because the faunal changes, like the stratigraphic changes, are gradual. It is unnecessary to point out here striking and well-known examples of such occurrences.

Aside from the fossils given in the tables, Doctor Gould has forwarded me several specimens of dolomite with *Pleurophorus* sp., and *Schizodus* sp., the latter very similar to one of those described later. These are not sufficiently well preserved to be identified with certainty and are omitted.

Species.	Enid-Wichita.	Whitehorse.	Quartermaster.
Paralegoceras baylorensis (White)	x		
Waagenoceras cumminsi White	x		
Medlicottia copei White	x		
Popanoceras walcotti White	x		
Orthoceras rushensis McChesney?	x		
Temnocheilus winslowi (Meek and Worthen)	x		
Tainoceras occidentalis (Swallow)	x		
Nautilus ——?	x		
——?	x		
——?	x		
(Endolobus) ——?	x		
Strophostylus remex (White)	x		
Naticopsis shumardi McChesney?	x		
Euomphalus subquadratus Meek and Worthen	x		
——?	x		
Murchisonia ——?	x		
Lepetopsis? ——?	x		
Bellerophon crassus Meek and Worthen	x		
Patellostium montfortianum Norw. and Pratt	x		
Bellerophon ——?	x		
Sedgwickia topekaensis (Shumard)	x		
Pleurophorus ——?	x		
Modiola subelliptica Meek	x		
Yoldia subscitula Meek and Worthen	x		
Myalina permiana Swallow	x	?	
aviculoides Meek and Hayden	x		
perattenuata Meek and Hayden	x		
Pteria longa (Geinitz)	x		
Aviculopecten occidentalis Shumard	x		
Syringopora ——?	x		
Spirorbis ——?	x		
Estheria? minuta Jones?	x		
Cythere nebrascensis Geinitz	x		

Species.	Enid-Wichita.	Whitehorse.	Quartermaster.
Spirorbis sp		r	
Serpula? sp			rr
Bryozoan, encrusting		rr	
ramose		r	rr
Dielasma schucherti Beede		aa	aa
Solenomya sp		rr	
Edmondia rotunda, n. sp		r	r
cumminsi, n. sp			r
Conocardium oklahomaense Beede		c	
Cyrtodontarca gouldii Beede		c–a	c–a
multidentata, n. sp		r	r
parallelidentata, n. sp		c	c
Pseudomonotis? sp		r	
Myalina sp	?	rr	
Schizodus ovatus Meek and Hayden?		c	r
oklahomaensis, n. sp		rr	
Aviculopecten oklahomaensis, n. sp		a	r–c
vanvleeti Beede		c	r
Allorisma? albequus, n. sp		r	c
Pleurophorus albequus, n. sp		aa	a
albequus longus, n. var		c	r
Pelecypod sp			rr
Pleurotomaria capertoni, n. sp		r–c	r–c
agnostica, n. sp		r–c	
sp		rr	
Worthenopsis depressa, n. sp		r	
sp			r
Trepospira haworthi, n. sp		c	c
Murchisonia collingsworthensis, n. sp			r
gouldii, n. sp		x	x
Loxonema permiana, n. sp			r
Orthonema dozierensis, n. sp			rr
texana, n. sp		rr	c
Bulimorpha? alvaensis, n. sp		rr	
Capulus?? haworthii, n. sp			r
sellardsi, n. sp		c–a	
Strophostylus permianus, n. sp		a	r–c
Naticella transversa, n. sp			r
Plagioglypta?? sp			rr

So far as known, the vertebrate fauna of the Red Beds is confined to the equivalents of the Enid formation, or nearly so. They have already been enumerated, and it is not necessary to repeat them here.

The striking differences between the Oklahoma-Panhandle fauna and that of the Wichita-Clear Fork fauna, as described by White, is brought out clearly by the table just given. However, it is to be remembered that the Wichita material is a limestone fauna, while the fauna of the upper beds is a sandstone fauna.

Another fact shown by the table is that the fossils of

American affinities represented in the Whitehorse sandstone show a decided decline in the Quartermaster beds, while the reverse is true of the foreign element, probably due to slower immigration.

DESCRIPTION OF SPECIES.

The drawings of the last two plates and text figures of this article are by Miss Maud Siebenthal, of Bloomington, Ind.

SPIRORBIS sp.

Plate VI, figure 10.

Shell minute. Only the attached surface of the two flat whorls shown on the cast of a shell. For the first half whorl the shell is nearly straight. The curve of the spiral begins abruptly. Greatest diameter a little less than a millimeter.

Whitehorse spring, Oklahoma; rare.

SERPULA? sp.

Plate V, figure 5.

A very minute cast of a serpulid (?) worm on the internal cast of a shell. The greatest diameter of the coil is about a half millimeter.

Dozier, Tex.; very rare.

STENOPORA sp.

A species, probably of this genus, was found at Whitehorse spring and at Dozier. Prof. A. F. Rogers writes me that it is practically impossible to identify them, stating: "I would call the one from Dozier *Stenopora* sp., and the one from Whitehorse the same." There was also an encrusting form from Whitehorse.

DIELASMA SCHUCHERTI Beede.

Plate V, figures 1-1*m*.

Dielasma schucherti Beede. Inv. Pal. Red Beds, p. 7, plate I, figs. 1-1*c*, 1902.

Shell rather small, biconvex, biplicate, subelliptical in outline, slightly tapering at the beak. The cast shows an arcuate pedicle valve, nearly equally convex except in front where it becomes somewhat flattened and contains two depressions, corresponding to the two folds in the other valve. The first

indication of the fold and sinus first appears in pretty large individuals and shows the ordinary fold of a *Dielasma*, the biplicate character appearing only in well-developed individuals. Along with this development comes a peculiar change in the form of the shell. It nearly ceases to grow laterally, and the additional growth takes place largely on the anterior margin, which narrows and becomes cuneate in longitudinal section. At the time when the biplication first becomes noticeable the shell is relatively very much broader than in the adult stage. The dental lamellæ are well developed in the adult individuals. They began to appear at a somewhat earlier stage than the biplication, but are not shown until the specimens reach a length of over seven millimeters. These plates, in the cast, give the appearance of a subquadrangular foramen; however, the foramen was nearly circular. In the brachial valve the features are similar to those of the pedicle valve, except that it is more convex and its lateral edges much more elevated. In the young specimens the muscular impressions seem to have sunken deeply into the shell itself. In larger ones the shell seems nearly plain within, while in the adult specimens there seems to be a cast of a true platform characteristic of the *Dielasmas*. The crural lamellæ are not very strikingly developed, though present. No specimens with the loop preserved have been seen in the fossils from Oklahoma. Two specimens from Texas show the loop very well, as shown on plate V. One of these is somewhat smaller than the other, and the loop is not yet united; in the larger one it is complete. These specimens are not over half grown. The adult form would doubtless show some further modifications.

Whitehorse spring, Oklahoma; very abundant. Dozier, Tex.; very abundant.

There is a large valve in the Oklahoma collection showing four plications instead of two. This is probably a pathologic specimen, or may represent another species. The tendency to produce abnormalities in this fauna is rather marked.

The surface of specimens of this species seems to have been smooth except for occasional growth marks. The shell was punctate, as is clearly shown in a specimen with a portion of

the shell preserved in the mold. The proportion of young specimens to fully developed adults is about 80 : 1, probably due to unfavorable environment.

SOLENOMYA sp.

Plate V, figure 4.

The cast of a small *Solenomya* of a comparatively low, long form. The details of the surface ornamentation and the end of the specimen are not preserved on the specimen figured. What appears to be the long end of another individual has the shorter end gone, so it is impossible to identify it specifically. However, I have seen no other species identical in form with it. Greatest length, 11 mm ; height, 4 mm.

Whitehorse spring, Oklahoma ; very rare.

This species has much the form of *S. biarmica* de Vern., of Great Britain, but the ridge in the shell in the umbo curves more sharply to the rear (short end) as shown in our casts. They show what are probably the traces of fine radiating lines in the shell, though they are hardly distinct enough to be reliable.

EDMONDIA ROTUNDA, n. sp

Plate VII, figures 3-3*b*.

Shell ovate, approaching semicircular outline, gibbous. Beak gibbous, elevated, subcentrally located. The entire shell is quite convex. Margins regularly rounded at both extremities and rounding up to the nearly straight hinge. Surface ribs impressed on the cast. Excavation formed by the platform beneath the beaks plainly visible. Length, 6.25 mm. ; length of hinge, 4 mm. ; distance from beak to front, 2.5 mm. ; height, 4 mm.

Whitehorse spring, Oklahoma ; rare. Dozier, Tex. ; rare.

This species may be distinguished from *E. cumminsi*, *postea*, by its more rounded outline, greater convexity, and more centrally located beak. This species is probably closely related to *E. semiorbiculata* Swallow, from near Council Grove, Kan., but, judging from his description, is much smaller and beaks are more prominent.

EDMONDIA CUMMINSI, n. sp.

Plate VII, figures 4, *4a*.

Shell small, transversely elliptical, rather compressed laterally. Relation of height (hinge to ventrum) to the length is about 7½ to 9 mm. Hinge comparatively straight, about three-fourths as long as the shell, rounding into the anterior and posterior outlines on either end, more rapidly on the anterior. Beaks only moderately prominent, situated a little in front of the middle, incurving forwards. Valves only moderately convex. The cast of the platform beneath the beak is well developed in the type specimen. The cast has only extremely faint traces of the surface undulations impressed on the umbonal ridge.

Dozier, Tex.; rare.

This species differs from *E. rotunda*, *ante*, in the length of the hinge, less convexity of the valves, and somewhat more appressed beak.

CONOCARDIUM OKLAHOMAENSE BEEDE.

Plate VII, figures, 2-*2f*.

Conocardium oklahomaensis BEEDE. Inv. Pal. Red Beds, p. 6, pl. I, figs. 3-*3c*, 1902.

Shell attaining moderate size, thick, and typically conocardiiform. Anterior and posterior lengths of the shell about equal, posterior abruptly truncated and then tapering to the point of a long tube. The beaks are centrally located, the carina very strong, angular, and oblique. The anterior portion tapers gradually to the end of the shell, where it turns somewhat downward and is abrubtly cut off. The posterior ventral outline is decidedly sinuate. The surface of the anterior part of the shell is marked by very coarse radiating costæ, eight or ten, in an adult individual, and about a half-dozen coarse concentric ridges, producing a very rough, cancellated appearance. The region of the carina is covered with very fine concentric laminæ, and the posterior side of it by nearly equally fine radiating lines producing a fine cancellation. There are also four to six radiating ribs on the posterior side of the carina. Length, 17+ mm.; height, 7 mm.

Whitehorse spring, Oklahoma; common.

The only other *Conocardium* that I know of occurring in the Permian is found in the valley of Palermo, and belongs to a decidedly older horizon. It is a very different form from ours.

CYRTODONTARCA Jak.

So far as observed, our fossils from the Red Beds do not have the vertical cartilage pits on the area, as figured by King for *Bakewellia*, and, instead, seem to show only horizontal striations. The dentition seems to be somewhat similar in both genera. Our specimens are referred to *Cyrtodontarca*.

CYRTODONTARCA ? GOULDII Beede.

Plate VI, figures 1–1c.

Bakewellia gouldii Beede. Inv. Pal. Red Beds, p. 5, pl. I, figs. 2–2*c*, 1902.

Shell of moderate size, aviculiform, compressed, thin, considerably longer than the hinge. Beaks low, subterminal; umbonal ridge well defined. Anterior ear nearly obsolete; posterior one alate, not sharply separated from the body of the shell. Border sinus very shallow, anterior margin rather sharply and regularly rounded, ventral margin gently curved posteriorly and nearly straight in front, rounding abruptly to the end of the hinge. There is rarely any indication of a sinus in the adult left valve, though slight ones are sometimes seen in the younger specimens. There is usually a slight depression extending from the front of the beak a little obliquely backward nearly to the margin of the shell. The hinge of the left valve is armed behind with one lamellar tooth which is nearly parallel to it, and the anterior part with a rather complex dentition. There are two diagonal teeth beneath the beak, lying about parallel with the axis of the umbonal ridge; in front of these is a third tooth, curved forward and enlarged to twice or three times the size of the others. Connecting with the lower end of this enlargement there is a ridge extending as a buttress downward behind what appears to be a semiobsolete muscular impression, somewhat as in the *Pleurophori*, though much less marked. Sometimes there seems to be a very slight, thin tooth in front of this scar. There is a strong muscular impression in front of the beak to the rear of the buttress. This scar, as

will be noted later, is prominent on some of the shells of this group.

So far as can be seen from our casts, the posterior adductor scar is large, and situated just above the umbonal ridge, opposite the extremity of the posterior tooth.

The form of the right valve differs from that of the left only in usually possessing a slight sinus in the ventral margin beneath the beak. The posterior end of the hinge is armed with two horizontal teeth instead of one. The anterior dentition is such as to correspond with the other valve. The surface of the shell seems to be marked with lamellar growth lines, arranged closely along the hinge and more remotely on the other parts. Length of hinge, 5.5 mm.; length of shell, 9.5 mm.; height at posterior end of shell, 5 mm.

Whitehorse spring, Oklahoma; common to abundant. Dozier, Tex.; common to abundant.

In some of the right valves of this species the buttress seems to be disconnected from the third tooth.

CYRTODONTARCA ? MUNTIDENTATA, n. sp.

Plate VI, figures 4, 4*a*.

Shell practically equivalvular, left may be a trifle the more convex, the form similar to the preceding species. There is a very slight sinus beneath the beak. The hinge has five teeth in the anterior end of the right valve and six in the left, with vertical buttress in addition. The posterior end of the hinge is furnished with two horizontal teeth to each valve. It may be, however, that the upper impression shown in the cast is a ligamental impression. The upper one is the more prominent of the two, the lower being more remote from the beak and smaller, and appearing only on the maturity of the shell. Length of hinge, 6 mm.; length of specimen, 10 mm.; height at posterior end, 5 mm.

Whitehorse spring, Oklahoma; rare. Dozier, Tex.; rare.

CYRTODONTARCA ? PARALLELIDENTATA n. sp.

Plate VI, figures 3-3*c*.

This species is more closely related to *Bakewellia parva* Meek, than any other species of the Whitehorse beds. It has a much closer relative, however, in an undescribed

species from the lower Permian of Kansas, though the characters of the muscular scars at once distinguish it. In form this species resembles the rest of the Red Beds species. Its distinguishing characters are two subparallel teeth on the anterior end of the hinge, the lower of which may be connected with the buttress. Posterior adductor large. Length of hinge, 5 mm.; length of specimen, 7.5 mm.; height at posterior end, 4.5 mm.

Whitehorse spring, Oklahoma; common. Dozier, Tex.; common.

The average umbonal angle seems to be larger and the shell somewhat broader with respect to the hinge than in the other species.

It should be remarked here that the forms of these species are not sufficiently well preserved to distinguish between them with certainty. It is very probable that with well-preserved material, showing all the critical features of each species, they might be readily separated. As it is, a specimen showing the outline or surface features does not have the teeth preserved, and *vice versa*.

PSEUDOMONOTIS Beyrich.

Hind[50] splits the genus *Pseudomonotis* into two genera, separating *P. hawni* Meek from *P. speluncaria* Schlotheim. His grounds for doing so are: "This species [*P. speluncaria*], however, has a peculiar posterior lobe separated from the rest of the valve by an oblique sinus; the left umbo is arched to a greater extent, and the hinge-line not so pronounced as in *Eumicrotis*." With these remarks the question is dismissed, and *Eumicrotis* of Meek is given to those shells without the sinus and lobe, while the others are apparently left with *Pseudomonotis* and regarded as Permian. This may hold for European specimens of this group, but it is very difficult of application in this country. Meek's discussion of the type species of his proposed genus *Eumicrotus*, which he afterward conceded to be synonymous with *Pseudomonotis*, will not be out of place here. It is as follows:[51]

50. Brit. Carb. Lam., II, pt. 2, pp. 41-44, 1903.

51. Pal. Upp. Mo., p. 55, 1864.

"In first describing this species, we called attention to its close relations to *E. speluncaria* Schlot. (sp.), and stated that we were aware it would not be easy always to find characteristic differences by which certain varieties of these two forms could be distingushed. Every naturalist, however, must have met with analogous cases, where the varieties of two closely allied but variable species approximate, and, as it were, mingle together, so as to render it sometimes extremely difficult to separate them; while the normal forms of each are so clearly distinct as to leave no doubt on the mind that they belong to different species. This, we think, is the relation the Kansas shells bear to *E. speluncaria*, although we are aware some of our friends entertain the opinion that they are not distinct.

"It is true some specimens agree almost exactly with such varieties of *E. speluncaria* as are represented by figures 15, 17, 20, and 21, plate XIII, of King's work on the Permian fossils of England; yet, out of hundreds of individuals collected and seen by us in Kansas, we have never met with one presenting the peculiar lobed and sulcated posterior so characteristic of the well-developed normal forms of *E. speluncaria*, such, for instance, as figures 5, 6, 7, 8, 9, 10 and 11 of plate XIII of King's work cited above. Again, none of our Kansas specimens, with a solitary exception, has had the beak of the right valve so gibbous, or near so elevated, as those represented by the figures last above cited; and in this single exception the shell differs so widely in other respects that, if not a monstrosity, we can but regard it as belonging to a distinct species from that under consideration, as well as from *E. speluncaria.*"

While differences of opinion as to the limits of definition of the species of the genus exist, most all will agree that it is an unusually variable one. I have quoted Waagen on this point already,[52] and agree very well with his conclusions.

In the Pennsylvanian and Permian of Kansas there are many of these fossils which possess the lobation of the shell to a varying degree. While I have studied many from the oölite of Kansas City and the Kickapoo limestone at Lawrence, and

52. Kan. Univ. Quart., III, p. 79, 1899. From Pal. Ind. Prod. Limestone Foss., III, p. 276.

the Permian rocks as well, where they occur in abundance, I hardly think I ever saw two of them with the same degree of lobation. It is true, however, that none of them possess such large lobes as those referred to by Meek and separated from *Eumicrotis* by Hind. Nevertheless the lobation exists, even in the type species of *Eumicrotis*, to some considerable extent among many individuals. To separate these out would be to split a single species into two genera. However, it should be remarked that the beaks are not so inflated and drawn out as in some specimens of *P. speluncaria* as figured by King. Neither are they so incurved over the hinge. But this feature also is an extremely variable one in our American species, and of itself is hardly of generic value. In the light of these facts it seems to me advisable to retain the term *Pseudomonotis* for the American fossils usually grouped under that term. Furthermore, I believe that they are sufficiently divided into species and varieties, with perhaps one exception, so far as they are known to me.

PSEUDOMONOTIS? sp.

Plate VII, figure 1.

Fragments of two flat valves, with very peculiar markings. The outline of the lower portion of the shell is nearly circular; the upper part unknown. The ribs are small and slender, flexuous, and made nodose by vaulted scales. They are spaced four times their diameter apart. There is occasionally a faint trace of an intermediate striation seen in the bottom of the broad, flat furrows. The whole area is crowded with fine, imbricating growth marks or concentric striæ. The length of the larger fragment is 24 mm.

Whitehorse spring, Oklahoma; rare.

The flexuous, nodular striæ remind one of *Pseudomonotis*, but it may belong to some other genus.

MYALINA sp

Plate VI, figure 7.

Shell rather small, quite elongate; beak apparently pointed. This specimen, the only one in the collection, has the beak broken away. The angle between the hinge and the front margin is about 38 or 40 degrees. The specimen is too frag-

mentary for specific determination. Length of specimen from point of broken beak, 17 mm.

Whitehorse spring, Oklahoma; very rare.

This shell seems to be closely related to *M. permiana* and *M. cuneiformis* Girty, so far as general form goes. It may be identical with the latter, but I think it is not.

SCHIZODUS OVATUS MEEK?.

Plate VII, figures 7, 7*b*.

Shell of moderate size; not very convex; hinge rather short; beaks prominent; umbonal ridge well defined, subangular; relation of height to length in perfect specimens probably a little less than three to five. Anterior outline from beak downward ovate; ventral border elliptical; postero-ventral border semitruncate, posterior nearly straight. The beaks are incurved. Some of these specimens show traces of concentric undulations. Three specimens. Height, 18, 14, 18 mm.; length, 26, 19, 23.5 mm., respectively.

Whitehorse spring, Oklahoma; common. Dozier, Tex.; rare.

The *Schizodus* material in these collections is unsatisfactory. In the previous paper there were two species represented. However, they were destroyed in the fire at University of Oklahoma, and good material is wanted in our collections, except for immature specimens, which are not satisfactory in critical work.

SCHIZODUS? OKLAHOMAENSIS, n. sp.

Plate VII, figure 6.

Shell rather small and schizodiform. Beak very prominent, highly elevated, rather sharp, nearly vertical, almost centrally located, and curving inward. The hinge is comparatively short, so far as shown in the specimen. Posterior umbonal ridge very prominent. The anterior margin slopes obliquely downward from the beak, and rounding sharply into the elliptically curved ventral margin. Postero-ventrally the margin curves abruptly upward at the foot of the umbonal ridge, making the lower posterior border truncate, the upper portion bending to the hinge at an obtuse angle. The convex portion of the shell is marked with heavy undulations,

in a manner approaching some of the Mesozoic members of the family. Length, 12 mm.; height, 8 mm.; beak, 5.5 mm. from front.

Whitehorse spring, Oklahoma; very rare.

This may not be a *Schizodus*, but the hinge is so poorly preserved that none of its characters are shown. It seems to resemble *Schizodus* as much as anything else, and is provisionally referred to it.

AVICULOPECTEN OKLAHOMAENSIS, n. sp.

Plate V, figures 3-3c; plate VI, figures 11-11c.

Shell like *A. occidentalis* in most of its features, and may be but a variety of it. The hinge is nearly equal to the length of the shell. The beak projects above the hinge, is acute, and in many spcimens is inflated, erect, or slightly inclined forward. Anterior ear well defined, convex, rounded at the extremity, separated from the umbo by an angular depression and is marked by about nine coarse radiating striæ or costæ and covered with close-vaulted scales. Little can be made out of the posterior ear of the left valve, except its general form, which is quite angular. It is separated from the shell by a rounded furrow. The posterior ear appears to be about as long as the anterior, and nearly smooth except for concentric lamellar markings. The surface is marked by two- or three-ranked costæ, according to their age, the later ones being smaller and implanted between the larger ones. They are straight or somewhat flexuous, flattened, and separated by furrows of about their own width. These are crossed by rather coarse lamellæ which may be rather distant or crowded, depending on the rate of growth of the individual at any point. These lamellæ are coarser than those of *A. occidentalis.* Right valve, probably belonging to this species, nearly flat, beak not elevated, outline and ears much as in the left valve, except the anterior ear, which is deeply cut by the byssal notch. Both ears show faint radiating costæ and concentric marks. Body of the valve nearly smooth, with but trace of radiating costæ.

Whitehorse spring, Oklahoma; abundant. Dozier, Tex.; rare to common.

The only distinctions between this species and *A. occidentalis* Shumard are the (frequently) smaller angle of the beak, which is a little more projecting, the extreme scaly appearance of the anterior ear, and the more pronounced character of the concentric lamellæ of the body of the shell. In old specimens some of the costæ become somewhat enlarged, as in *A. vanvleeti*, but there is little danger of confusing it with that species.

AVICULOPECTEN VANVLEETI Beede.

Plate V, figures 2-2e.

Aviculopecten vanvleeti Beede, Inv. Fauna Red Beds, p. 6, pl. I, fig. 8, 1902.

Shell large, of variable form. Ears well developed, distinct and prominent. The outline of the shell is much the same as in *A. maccoyi*, and the surface marks are similar in most respects. The beaks are prominent and elevated above the hinge, gibbous. Hinge nearly straight, about three-fourths the length of the shell; anterior ear convex, separated from the umbo by a deep sulcus, and the anterior margin is deeply sinuate on its lower side. Posterior ear nearly flat, about as long as the anterior one, separated from the umbo by a less distinct sulcus, and the posterior margin is made gently sinuate by it. The surface is marked by two-ranked radiating costæ. Three to six of these are much larger, and appear to be nodular in the cast, probably caused by vaulted lamellæ. Between each of these are six to fifteen smaller, rather sinuous, striæ, which increase by implantation, and are rounded, low, separated by interspaces equal to their width, and crossed by concentric lamellar markings and larger varices of growth. The larger costæ do not become well developed until 15 or 20 mm. from the point of the beak, though they are usually traceable nearly to the point. No specimen before me possesses both ears, but one specimen possesses a posterior ear with five longitudinal striæ, while another individual shows eight or ten ribs bending downward on the anterior ear.

Whitehorse spring, Oklahoma; common. Dozier, Tex.; rare.

This species can be distinguished from *A. maccoyi* Meek

and Hayden, by its larger size and especially the larger striæ, which are not strikingly prominent until 15 or 20 mm. from the beak, while those of *A. maccoyi* Meek and Hayden, are equally distinct 3 to 5 mm. from the beak. Otherwise they are very similar. The general appearance of the shell is a trifle like *A. occidentalis* Meek, but is at once distinguished from it by its larger ears with coarse marks and the nodose character of the larger ribs.

ALLORISMA ? ALBEQUUS, n. sp.

Plate VII, figures 5-5c.

Shell minute, equivalvular, subquadrilateral, beaks prominent. The anterior margin descends obliquely from the beak to the anteroventral region where it is abruptly rounded. Ventral margin is slightly sinuate because of the faint depression extending obliquely backward and downward from the beak. Posterior margin pretty regularly rounded, meeting the hinge at a very oblique angle. Hinge straight, its other characters unknown. The beaks project above the hinge and are incurved forward. The surface was probably nearly smooth, with faint undulations of growth. Two specimens: Length, 5.5 mm., 4.5 mm.; height, 2.25 mm., 2 mm., respectively. Length of hinge, 2.75 mm. and 2 mm.

Whitehorse spring, Oklahoma; rare. Dozier, Tex.; common.

These fossils have the general expression of the *Allorismas*, and are provisionally referred to them until material demonstrating the character of the hinge dentition can be had.

PLEUROPHORUS? ALBEQUUS, n. sp.

Plate VI, figures 8-8e.

Pleurophorus sp. BEEDE, Inv. Pal. Red Beds, p. 9, pl. I, fig. 4, 1902.

Shell of medium size to rather small for this genus; height at the beak about one-third the length; beak rather prominent, nearly terminally located, projecting above the hinge; umbonal ridge not sharply defined, but well rounded; in front of the ridge is an undefined oblique depression, frequently producing a slight sinuosity in the ventral margin. Hinge very slightly arcuate and long. The anterior outline slopes and rounds obliquely downward, merging into the ventral

margin, which may be nearly straight and nearly parallel to the hinge or a little sinuate. Posterior extremity rounded and meeting the hinge at a very obtuse angle. Valves about equally convex. The semielliptical adductor scars are very deeply impressed, with the strong ridge of shell behind fading out toward the base of the shell. The pedal scar, situated above and back of the adductor, is very small. Cardinal teeth two, one nearly parallel to the hinge, while the other rests more obliquely over the adductor impression. A faint line indicates a slight forking of the upper tooth in some casts. The posterior teeth are shown in the casts as being nearly parallel to the hinge, but diverging downward from it at a slight angle. The tooth on the left valve is more strongly developed than the one on the right, the latter not being preserved in the great majority of casts. The matrix is coarse material and poorly adapted to preserving the finer marks or ridges. The surface is marked by growth lines which are strongest on the anterior part of the shell, two to five or six faint radiating lines extending from the beak to the posterior end of the shell and "granulations" on the depression below the beak. The ligament is external, situated in grooves. Length, 14 mm.; height, 5.5 mm.

Whitehorse spring, Oklahoma; very abundant. Dozier, Tex.; common.

This species differs from *P. occidentalis* Meek and Hayden in being larger, having an arcuate hinge, and in having the pedal scar farther back, judging from his description. It differs from *P. oblongus* Meek in being proportionally much longer and in possessing radiating ridges. Compared with *P. subcuneatus* Meek and Hayden, our species has the ridge of shell back of the adductor scar extending somewhat backward rather than vertical, as well as much narrower and more sharply defined. The umbonal ridge is more poorly defined on our specimens, which also show two to six radiating ridges. There also appears to be some difference in the dentition.

Our species seems to be closely related in general appearance, at least, with *P. meeki* Walcott, but does not widen

very distinctly posteriorly, and the beak appears to be situated farther back.

These shells differ from the known *Pleurophori* in the possession of *Allorisma*-like "granulations" below the beak, which seem to be accompanied by the vaulting at this place of the lamellæ of growth. The granulations are roughly arranged in radiating rows. This shell has, so far as may be determined from the material at hand, the external characters of *Pleurophorella* Girty. However, he allies that genus with *Allorisma*, as a probable subgenus. Our specimens are certainly closely similar to *Pleurophorus* in dentition, muscular markings, and form. If Girty's genus is closely related to *Allorisma*, as he thinks it is, we cannot refer our specimens to it. If parallel development is to be looked for among the pelecypods, where it seems to me to be very likely to occur, external features are of little value as generic criteria when the critical characters are unknown. At any rate, the Dozier and Whitehorse specimens cannot be referred, even provisionally, to *Pleurophorella* until Doctor Girty determines whether it belongs in the order *Anomalodesmacea* or the order *Teleodesmacea*.

Our specimens differ from the *Pleurophori* only in the possession of granulations on the region beneath the beak and perhaps a reduction of the upper cardinal tooth.

PLEUROPHORUS ALBEQUUS LONGUS, n. var.

Plate VI, figure 9.

More than three times as long as high, hinge usually straight, umbonal ridge very faint. Dentition as in the preceding species. Some of the valves show angulation on the posterior end just below the hinge line. No definite radiating ridges seen on adult specimens, though they may be present, as the larger the specimen the more poorly it is preserved in these rocks. The depression beneath the beak appears to be missing and the ridge back of the adductor impression is nearly vertical. Otherwise as in the species. Two specimens: Length, 27 mm, 13 mm.; height, 7 mm, 4 mm., respectively.

Whitehorse spring, Oklahoma; common. Dozier, Tex.; rare.

PELECYPOD, sp.

Shell small, subelliptical; beak moderately prominent, projecting, located more than a third the distance from the anterior to the posterior end of the shell. Hinge straight or very slightly arcuate, much shorter than the shell No indications of cardinal characters visible. The margin in front of the beaks slopes obliquely to the end of the shell, where it rounds off in an elliptical curve to the base, which is nearly straight, but somewhat convex. It rounds in an elliptical curve to the hinge, which it meets at a very obtuse angle. The entire valve is moderately convex, most convex on the umbo. Surface marks unknown. Length, 6 mm.; height, 3.5 mm.

Dozier, Tex.; very rare.

The generic as well as the specific characters of this shell are not sufficiently shown to make an attempt at identification worth while.

PLEUROTOMARIA CAPERTONI, n. sp.

Plate VIII, figures 9–9c.

Shell small, robust; whorls five, quite convex, rapidly enlarging, sutures deeply impressed. Below the suture and above the band there are three, occasionally but two, revolving lines, the lowermost of which is the largest. The keel is large and rounded, with a moderately narrow concave band below it. The band has a minute, thread-like revolving line in the center. The lower side of the band is bordered by a ridge smaller than the upper one. There are six revolving lines on the body whorl below this ridge. One of these appears on the spire between the band and the suture. The mold shows crowded, sharp growth lines transverse to the whorls, which appear to arch backward on crossing the band. Apical angle, 45–50 degrees.

Dozier, Tex.; Whitehorse spring, Oklahoma.

This species is closely related to *Worthenopsis kschertianæ-*

formis Jakowlew, but differs in having more ventricose and less angular whorls, sometimes three lines on the spire above the carina and a smaller apical angle. It is strikingly similar to *Turbo helicinus* (Schlotheim), from the British Permian. Inasmuch as the presence of the slit has not been determined with certainty in the specimen at hand, it is possible that they are very closely related.

PLEUROTOMARIA AGNOSTICA, n. sp.

Plate VIII, figures 13*a*, *b*.

Shell small, spire elevated, whorls five or six, suture distinct, slit high and rather deep, placed on the upper angle of the whorl, umbilicus open and small. The upper surface of the whorls is somewhat convex in the casts. The edge of this flattened region is quite obtusely angular, below which the shell is rounded to the lower third of the whorl, where it curves sharply into the base. Shell ornamented by several revolving striæ on the upper two-thirds of the whorl. The casts show no marks on the lower third of the body whorl. The shell is thick at the keel, and on the upper whorls about four strong revolving lines may be distinguished in the edge of one mold. There are faint indications on the cast of one or two broad lines above the keel. No transverse markings are shown on the specimens before me. Height of spire about 7 mm.; of body whorl, 2½ mm.; diameter of body whorl, 4½ mm.

Whitehorse spring, Oklahoma; rare to common.

This species is related to *P. humerosus* Meek, but is a more slender species with a stronger keel. It would also seem to be related to *P. proutana* Shumard, but the carination is above the middle. It differs from *P. perornata* Shumard in not having strong transverse markings.

WORTHENOPSIS? DEPRESSA, n. sp.

Plate VIII, figures 4, 4*a*.

Pleurotomaria sp. Beede, Inv. Pal. Red Beds, p. 7, pl. I, figs. 13, 13*b*, 1902.

Shell of moderate size, spire quite depressed. There are three of four vertically compressed whorls. The body whorl expands rapidly, nearly flat on top, the outer edge keeled and angular, the angle being somewhat larger than a right angle;

the outer portion of the whorl is nearly vertical or a little concave, rounding off into the convex lower side. The suture is well defined, so far as may be determined from the cast. The umbilicus is rather wide, but from our specimens it cannot be told whether it was closed or open. A cross-section of the body whorl is subquadrate. The surface of the shell was ornamented with six or seven revolving striæ on the upper side of the body volution, eight or nine around the periphery, and probably a larger number of finer, more crowded ones on the lower side. No indications of transverse striæ or growth marks are shown on our casts, though doubtless the shell had fine lines of this character. Height, 6 mm.; width, 9.5 mm.; height of body whorl, 4 mm.

Whitehorse spring, Oklahoma; rare.

This species would seem to be very distantly related to *Pleurotomaria linkiana* King, from the English Permian, so far as form and surface features are concerned. Our species has a more depressed spire and is more angular than that species. It is much more closely related to *Worthenopsis dejactinensis* Jakowlew, from Russia.

WORTHENOPSIS sp.

Plate VIII, figure 13.

Shell very small, whorls five or more, sutures deep. The whorls are compressed vertically, sharply angular, and bicarinate, a single carina showing on each whorl of the spire about two-thirds the distance from the upper to the lower suture. The whorls are vertically compressed, sharply angular, with a concave band. The top of each succeeding whorl is wound along the middle of the band, concealing the carina on the lower side. On the body whorl the carina below the band is less prominent than the one above it and is less distant from the axis of the shell. Other characters unknown. Height, 2 mm.; width about 1.5 mm.

Dozier, Tex.; rare.

This species may be distinguished at once by the angularity of its whorls and the fact that only the upper keel shows on the spire.

TREPOSPIRA HAWORTHI, n. sp.

Plate VIII, figures 8-8*b*.

Shell small, spire turreted, whorls enlarging rapidly, keeled, and sharply angular. The upper part of the whorls are obliquely flattened for a short distance to the edge of the keel where they bend abruptly downward and round off below. There is somewhat of a callosity in the region of the umbilicus. There are about four whorls in the adult shell. The surface is ornamented with about eighteen fine revolving striæ, five of which appear above the carina and about thirteen below it. Near the umbilicus these lines are quite fine. About two or three of the lines below the carina are visible on the upper whorls of the shell. The suture is very distinct. Some Texas specimens show fine, elevated, crowded, transverse striæ. The height of a complete specimen would be about 3 mm.; width, $2\frac{1}{2}$ mm.; height of lower whorl, 2 mm.

Whitehorse spring, Oklahoma; common. Dozier, Tex.; common.

This species is related to *P. humerosa* Meek, but the much smaller size ($\frac{1}{8}$) and greater number of revolving striæ will at once distinguish them. Judging from our casts the shoulders of the Red Beds specimens must have been quite as prominent as those on the Pennsylvanian species just mentioned. It also resembles *Trepospira dives-ouralica* Jakowlew, from Russia, but has a much higher spire and is a very much smaller species.

MURCHISONIA COLLINGSWORTHENSIS, n. sp.

Plate VIII, figures 7, 7*a*.

Shell of moderate size, acute; suture impressed; whorls enlarging very gradually; keeled; umbilicated below. The whorls are beveled slightly outward from the suture, thence falling nearly downward with a slight concavity (shown in the best squeezes), producing a low, undefined ring, scarcely perceptible, just below the suture. A little over half the distance to the suture below is a prominent, rounded keel. The lower side of this keel is somewhat concave nearly to the suture below, where about half the ridge below the keel shows above the suture. On the body volution the keel is

located just a trifle above the middle, followed by a second, much fainter one, below it. The two are separated by a concavity. The base rounds off rapidly below the keel. The nature of the apertural region is unknown. The surface is marked, as shown in the mold, by slightly flexuous growth lines bending backward on the keel. Apical angle about 42 degrees.

Dozier, Tex.; rare.

This species differs from *M. texana* in having a larger apical angle, the band higher above the suture, more prominent, and sharper. It differs from *M. golowkinskii* Jakowlew in having a larger angle of divergence (42 degrees instead of 28 degrees), and possibly some details of the body whorl.

MURCHISONIA GOULDII, n. sp.

Plate VIII, figures 6–6*b*.

Shell small, narrowly trochiform; whorls about seven, keeled, regularly expanding, angular; sutures distinct. There are three revolving ridges on the shell, the upper bordering the suture, the middle one forming the prominent keel in the middle of the volution, and a lower one covered by the upper one in the spire, a short distance below the keel. The interspaces are concave. The upper ridge makes the suture canaliculate. On the body whorl the shell strikes suddenly off below the lower ridge, leaving the base of the body whorl nearly flat. The surface is marked on the band and above it by fine revolving lines. None have been seen below.

Whitehorse spring, Okla.; Dozier, Tex.

This species may be distinguished from *M. collingsworthensis*, *ante*, by the fine revolving lines on the band and above it.

LOXONEMA PERMIANA, n. sp.

Plate VIII, figures 14, 14*a*.

Shell minute, acutely pointed, very slender, the suture distinct. There are probably eight or ten whorls in an adult specimen, enlarging very slightly, with moderately deep sutures. The distance from suture to suture on the lower portion of the spire is about equal to the diameter of the shell

at that place. Apex of the spire and base of the body whorl unknown. Surface apparently without ornamentation.

Dozier, Tex.; rare.

This species differs from *L. peoriensis* Worthen in having more convex whorls and deeper suture.

ORTHONEMA DOZIERENSIS, n. sp.

Plate VIII, figure 8.

Shell small, plane, enlarging very slowly; suture narrow, impressed. The spire of this shell seems to be entirely plane except for the impression of the linear suture. The base of the body whorl is angular, sloping rather abruptly inward. Below this angulation there is a revolving ridge.

Dozier, Tex.; very rare.

This species resembles *O. texana* in general appearance, but has no ring at the suture. It differs from *O. salteri* M. & W. in being more slender and devoid of revolving lines on the spire. It differs in this respect from *O. carbonarium* of Worthen. It is more closely related to *O. conica* M. & W., but is a more robust and less acute shell.

ORTHONEMA? TEXANA, n. sp.

Plate VIII, figures 5, 5*a*.

Shell of fair size, spire trochiform and acute, whorls eight or ten, enlarging very gradually. Suture distinct and impressed. Below the suture, in the spire, the shell is beveled outward for a short distance, whence it turns downward with a concave outline, forming a slight ring below the suture. The middle of the whorl is slightly concave, ending in a sharply rounded elevation immediately above the next suture. On the body whorl, below the carina just mentioned, there is a second but smaller ridge, followed by a third, which is still weaker; below this there is a relatively broad, slightly concave area and a fourth angular ridge, followed by one or two indistinct lines surrounding the umbilical region. Below the two larger carinæ the shell falls off very abruptly. The only transverse marks visible on the squeeze or mold are very faint indications of fine growth lines. 4.5 mm. × 10.5 mm. Apical angle about 33 degrees.

Dozier, Tex.; common. Whitehorse spring, Oklahoma; rare.

This species resembles two species from the Illinois Pennsylvanian, *O. carbinarium* Worthen and *O. salteri* Meek and Worthen. It may be distinguished from either species readily enough by its having a heavy revolving ridge just above the suture, and a very faint one below it. The relative depth of the whorl is also less.

So far as general appearances go it could be compared with *Turritella excavata* Laube, from the Triassic, from which it differs in having twice the apical angle and in having the prominent ridge above the suture rather than below it.

BULIMORPHA? ALVAENSIS, n. sp.

Plate VIII, figure 11.

Shell of moderate size, rather high, sutures distinct. Height of body whorl, 8 mm., next succeeding, 3½ mm., and the third, 2½ mm. The apical angle as shown in the cast is about 38 degrees. The probable number of whorls is about six. The aperture appears to be semipyriform. Diameter of the base, 6 mm. There is somewhat of a shoulder beneath the suture, below which the shell is nearly flat, until the lower portion of the whorl is reached, where it rounds off quite rapidly. The specimen is somewhat compressed in a plane parallel with the axis of the shell.

Whitehorse spring, Oklahoma; very rare.

This species seems to be related to some of the species *Bulimorpha* or *Machrocheilus* from the Kansas Pennsylvanian, but is specifically identical with none of them, so far as the characters are exhibited in the cast at hand. The generic reference is provisional.

CAPULUS? HAWORTHI, n. sp.

Plate VIII, figures 12-12*b*.

A small shell, the casts of which show no indisputable surface or muscular markings. It probably belongs to this or some gastropod genus, as *Acmæa*. They are obliquely conical, and the bases are pretty regularly elliptical. The height is about 3 mm., length about 5 mm., with the apex 3 mm. from one end.

Dozier, Tex.; rare.

CAPULUS SELLARDSI, n. sp.

Plate VII, figures 8-8f.

Shell of moderate size, regular in outline, with pointed beak. The beak is little elevated, has about half a turn, is acute, and twisted somewhat to the right. Aperture longitudinally ovate, edges regular, right side somewhat more excavated than the left near the beak. Surface beautifully ornamented with two sets of thread-like lines, the concentric being more distantly spaced near the beak. On the right lateral margin the radiating striæ become much larger and more distantly spaced and somewhat wavy. On the remainder of the shell the concentric lines are heavier. They are not imbricated in the region of the beak. They are minutely wavy on the front of the shell of some individuals.

Whitehorse spring, Oklahoma; common to abundant.

STROPHOSTYLUS PERMIANUS, n. sp.

Plate VIII, figures 2-2c.

Naticopsis sp. BEEDE, Inv. Pal. Red Beds, p. 7, pl. 1, fig. 12, 1902.

Shell moderately small, about three or four whorls visible on the costa, showing, so far as observed, no tendency to straighten out with age, as does *S. remex* (White). The surface is marked with transverse lines of growth which are unusually large for this genus and are pretty regularly spaced. They are not very much stronger near the suture than on the body of the whorl. Aperture elliptical. The columella seems to be present, but its nature cannot be determined with certainty. "Height of spire, 7 mm.; greatest diameter, 9 mm.; height of body whorl, 6 mm."

Whitehorse spring, Oklahoma; abundant. Dozier, Tex.; rare to common.

The shells of the Dozier specimens are somewhat smaller than those from Whitehorse spring. The growth lines are strong and sinuous, bending somewhat backward.

This species is most closely related to *S. remex* (White), but differs from it, apparently, in possessing no traces of revolving striæ, in having the body volution more closely coiled, and in attaining only half its size.

NATICELLA TRANSVERSA, n. sp.

Plate VIII, figures 1, 1a.

Shell small, spire low, whorls about three, rapidly enlarging. The spire is much appressed, rising but slightly. The upper whorls form but a small fraction of the height of the shell. The suture is strongly impressed, and just beneath it the shell is nearly flat and smooth for a very short distance, when it turns down abruptly with an angulation, below which the entire shell is ornamented with transverse ribs very equally spaced. They are about their own width apart, slightly keel-shaped, with rounded valleys between. Height of shell and greatest diameter about equal, 4 mm.

Dozier, Tex.; rare.

This species has a superficial resemblance to *Naticella costata* (Munst.), from the Triassic of St. Cassian, on the one hand and remotely to a species from the Kansas Pennsylvanian on the other. The generic reference is provisional. It also has a very strong resemblance to *Narica lyrata* (Phill.), from Belgium and England, but is a very different species. Attention should also be called to its resemblance to *Littorina biserialis* Phillips, as figured and described by Murchison, de Verneuil and Keyserling from the Urals of Russia. It differs very sharply from these shells in the relative height and form of the body whorl. It is to be remembered that our specimen only shows superficial characters, and that there is a great stratigraphic interval between the horizon of the European and American shells.

PLAGIOGLYPTA?? sp.

Shell minute, shaped like *Dentalium* and allied shells. The diameter at the larger end is about $\frac{2}{3}$ mm. It was ornamented with comparatively coarse annulations. The specimen is too fragmentary to admit of specific determination or correct generic reference.

Dozier, Tex.; very rare.

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SOME LABORATORY METHODS IN EMBRYOLOGY.

BY R. G. HOSKINS.

THIS paper is a description of some of the methods employed in the zoology department of the University of Kansas in the preparation and handling of material for routine work in embryology. There is not much herein that is original; it is rather a systematic arrangement of data adapted from many sources. The methods have this, however, to recommend them: they have all been found satisfactory under ordinary working conditions. The material used is mostly as follows: For holoblastic cleavages of the egg, the frog; for delamination and early organogenesis, the chick; and for later organogenesis, the pig. The method of preparing each for class use will first be given.

Frog eggs are collected in early May, in a rather extensive series of lots. From these are selected, if possible, the various stages desired. If any stages are lacking, a lot of younger age is kept in a dish of water exposed to bright sunlight until the right stage of development is reached. They are then preserved in four per cent. formalin until wanted. The stages used are 1-, 2-, 4-, 8-, 32- and 128-cell, early and late blastopore, and a stage showing the neural folds.

For chick material, a satisfactory supply of eggs can usually be obtained from some farmer without any special trouble. It is well, however, to get them in the spring, when the vitality of the eggs is strongest. These are placed in an incubator for the necessary time to secure embryos of any desired age. In reckoning the time to remove the eggs, one hour should be allowed in addition to that required for the desired develop-

ment, as it takes about that length of time for incubation to begin. The embryos thus secured are not of exactly uniform age, but a count of the number of somites affords a satisfactory check for chicks of from twenty to fifty hours, and the general appearance of the younger stages is characteristic; ordinarily, for stages older than fifty hours, the incidental variation in immaterial. In this laboratory the "Cyphers" hot-air incubator has proved very satisfactory. During incubation the eggs should be turned once or twice a day to prevent adhesions between the fetal and shell membranes.

After sufficient incubation the eggs are removed and the embryos secured by the following method: The shell is perforated at one side so as to avoid injury to the chick, which normally floats on the top. Then the shell is carefully removed, bit by bit, until a hole about the size of a five-cent piece is made. For this purpose a pair of curved forceps and a needle with a sharply recurved point are very convenient. The chick is now fixed *in situ*. This is much simpler and more satisfactory than the process frequently employed of floating out the egg in normal salt solution. Incidentally, however, this later process can occasionally be employed to advantage, as a last resort, in case of an embryo that is not normally oriented. The fixative used must be one that does not cause an adhesion between the vitelline membrane of the egg and the embryo. The following mixture has been found most satisfactory:

FORMO-NITRIC.

Ten per cent. formalin	3 parts.
Ten per cent. nitric acid	1 part.

This fluid requires from five to fifteen minutes for the fixation of embryos up to seventy-two hours old. For older chicks a subsequent treatment in this or some other good fixative is advisable.

After fixation is completed a disc including the embryo is cut out from the vitelline membrane by means of a pair of curved-pointed scissors. This disc for embryos up to twenty-four hours old should be about the size of a dime; then up to thirty-six hours of age the incision should follow the margins of the blastodisc, just outside of it; above this age any

desired amount of the fetal membranes may be included. The disc is now removed on a section-lifter to a Petri dish of water. By gentle manipulations the adherent yolk and the vitelline membrane can be floated loose from the embryo. In case they prove refractory a gentle agitation of the water by a pipette will usually dispose of the difficulty. At this stage great care is necessary.

For convenience in further manipulation it is advisable to harden the embryos, particularly if they are to be sectioned. They are carefully flattened in a vessel with a plane bottom —preferably a Petri dish—then treated with the hardening fluid —ten per cent. formalin saturated with mercuric chlorid. Only a few drops should be used, and this carefully applied, in order to avoid any folding or creasing of the blastodisc or membranes. After a treatment of from five to thirty minutes, the embryo is washed in running water from fifteen minutes to two hours—the length of time depending on the size. This step follows immediately after fixation, in case the hardener is not used.

For staining surface mounts for general microscopic study, Grenacher's alum-carmine is very satisfactory, but if the preparation is to be used with a projection lantern, borax-carmine is slightly better. For embryos that are to be sectioned, either of these may be used as an *in toto* stain, but it is often advisable to use others, staining on the slide. In this case the chick should be given an *in toto* stain with some such color as eosin; this makes it more easily seen, and hence less likely to injury in the manipulations of sectioning and mounting. This stain is later removed from the sections with alcohol and some other stain substituted. Mayer's hæmalum is perhaps the best for general purposes. Older stages should be stained very lightly. For clearing whole embryo preparations pure cassia oil has been found much superior to anything else; it causes very little shrinkage and does not make the material brittle, as do most other clearing agents.

To secure pig material in any considerable amount, it is necessary to visit a large pork-packing establishment. In any of these it is easy to secure embryos of any size from

5 mm. up to full term, and in any desired quantity. For this purpose it is sometimes recommended that a room be secured in or near the packing-house, where the pregnant uteri can be taken for examination. Unless, however, very small embryos are desired, this will not be found necessary. It is better to obtain a table in the cleaning room as close as possible to where the uteri are removed. This permits the handling of the material with much greater dispatch, with sufficient convenience for all practical purposes, and with little, if any, greater amount of incidental unpleasantness.

For equipment, the collector needs only a good supply of containers, a small graduate, fixatives, and, unless he is desirous of some special kind of material, one pair of small scissors; anything more is only in the way. For fixation, Kleinenberg's picro-sulfuric mixture has been found quite satisfactory for embryos up to 10 or 15 mm. long and Zenker's fluid for all sizes. The larger ones, however, must have the body cavity punctured to secure sufficient penetration of the fixative. Where the size of the embryo does not preclude its use, the former is the more satisfactory, both on account of the simplicity of the after-treatment required, and on account of the greater length of time material can be left in it. Later stages, for the purpose of dissection, are best preserved in Erlichi's mixture:

Potassium dichromate	2½ gr.
Cupric sulfate	1 gr.
Water	100 cc.

Containers of standard size should be used and the dry materials of the fixatives should be weighed out and carried in vials with sufficient amounts in each to make one container of fluid. It is more practicable, however, to carry the liquid ingredients in bulk and measure them out as needed. The mixing of the fixatives is thus very simple, since the only other ingredient, water, is always, in a cleaning room, near at hand. In case Zenker's fluid is used, enough Müller's should be taken to give each embryo a preliminary bath to fix the albuminates, which would otherwise impede the action of the former fluid.

The pregnant uteri can be distinguished by their greater

vascularity; also, in case of those containing embryos of greater length than 5 or 6 mm., by the series of enlargements that contain the latter. These uteri are selected and carried to the table for examination. Each of the previously mentioned enlargements is then slit open with the scissors. This will also slit the false amnion, thus opening the vesicle in which floats, in a copious supply of fluid, the true amnion and its contained embryo. This is then seized and the false amnion, to which it is attached, severed with the scissors. For handling the embryos at this stage of the manipulations, fingers are preferable to any sort of forceps. After a sufficient number of embryos have been obtained and placed in the fixative, they are taken to the laboratory and, after fixation is completed, washed, sorted, and preserved in eighty per cent. alcohol until needed.

As in case of the chicks, the pig embryos to be sectioned should be given a preliminary stain with eosin before they are embedded. They are then sectioned at a thickness of from 10 to 20 microns, depending upon the size of the embryo. The sections are mounted on slides and the eosin removed. For staining, the most satisfactory results have been obtained by the following hæmalum-cochineal mixture: Equal parts of Minot's alum-cochineal and Mayer's hæmalum; this is followed by a counterstain of orange G. This method can be used with material fixed either in Zenker or picro-sulfuric. With this combination there is very little danger of overstaining; the cochineal has a retarding effect on the hæmalum, and finally so impregnates the tissue as to prevent overstaining with the latter. An excess of orange G can be easily corrected by an alcohol bath. This combination gives exceptionally good differentiation; the cochineal is selective for nervous tissue and brings out the various elements in the central nervous system particularly well, while the hæmalum gives a very clear nuclear stain. The orange G marks off distinctly both cell and basement membranes, as well as peripheral nerve fibers.

Each mounted embryo that is added to the collection is given an accession number. This is done whether it is put up as an exhibition specimen, either whole or dissected, or

sectioned and mounted on slides. In the latter case, each slide bears in the upper right-hand corner the accession number of the embryo and the number of the slide in the series. (Thus the fifth slide of embryo No. 70 would be marked $\frac{70}{5}$.) This marking is done permanently with a diamond point; this obviates the annoyance incident to the loss of paper labels; these can, however, be used in addition to the numbers, with advantage in some cases. A record of each embryo and slide is kept by a card catalogue system. For this purpose a set of cards has been devised by Mr. R. E. Scammon, of this department. He, however, expects to describe these in a separate paper.

For class use, any series can be divided up into sets as desired, as brain sets, heart sets, etc. For containers of these sets, the flat, pressed-board boxes manufactured by Theodore Schröter, of Leipzig, are very convenient. They can be obtained of various sizes as desired, and have the advantages of compactness and lightness. For storing series of more than six slides, ordinary slide boxes of 100 capacity are used. Standard sets are filed away in the flat containers, but incidental sets are better reassembled in their regular containers when not in use. This system of handling them makes any slide of a collection of any size available for instant reference. It also reduces to a minimum the work of keeping the collection in order, since any "stray" slide can be quickly restored to its place at any time.

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A METHOD OF RECORDING EMBRYOLOGICAL MATERIAL.

BY RICHARD E. SCAMMON.

THE cataloguing and arrangement of an embryological collection of any size offers a problem of some complexity. Such a collection made up of embryos, entire and sectioned, separate organs and fetal appendages, does not lend itself at once to a simple classification or an easy system of arrangement. In the method here presented an attempt has been made to avoid complexity as one extreme and incompleteness as the other. The system set forth below was worked out by the author, with suggestions from Dr. C. E. McClung and Mr. R. G. Hoskins for the growing collection of the University of Kansas. Thus far it has proved satisfactory, and rendered the collection far more available.

This method has for its aim three results: First, to give quickly accurate data concerning any specimen in the collection; second, to prevent the loss of specimens and slides from the collection; third, to systematically collect and preserve valuable observations concerning the material in the collection. The means used is a series of records kept on specially devised cards. The method of procedure is as follows: Material for class use and dissection or unprepared for the collection is merely kept in bottles with slips giving all known data. When a specimen is to be sectioned or otherwise prepared for the collection it is given an accession number. Two series of accession numbers are kept—one the ordinary series of numerals for entire embryos, whole or sectional; the other a series with a cipher before the first numeral (example, 025)

for separate organs and fetal appendages. This number is placed in the upper left-hand corner of such a card as is shown in figure 1.* On this card are recorded all known data.

As the process of preparation is carried out the data concerning it are added in the appropriate places. The space under the heading "Remarks" is used mainly for notes on the condition, age and peculiarities of the embryo, together with reference numbers. Should the embryo be kept entire, or merely dissected, it is placed in an exhibit jar bearing the same number as the card, and the words "Exhibit jar" are written in the space under "Containers" on the card. The gummed numbers made by the Tablet and Ticket Company

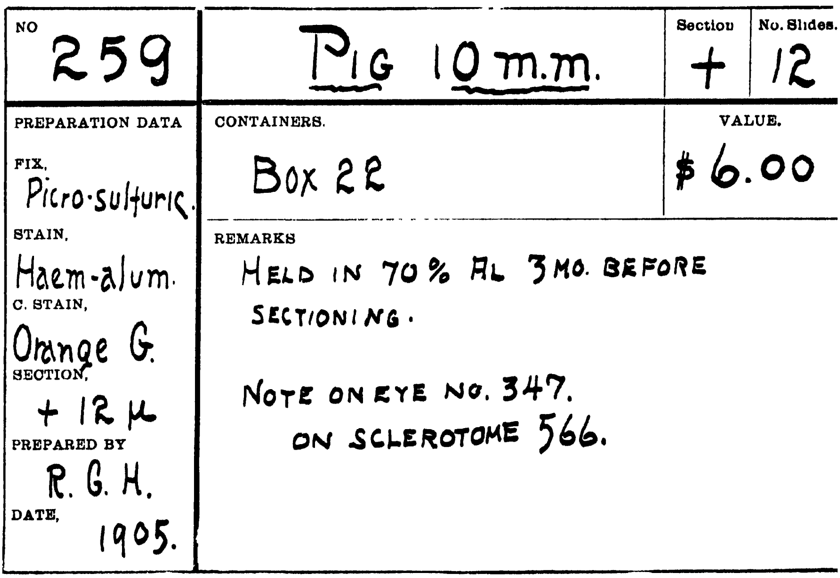

NO 259
PIG 10 m.m.
Section +
No. Slides. 12
PREPARATION DATA
FIX, Picro-sulfuric.
STAIN, Haem-alum.
C. STAIN, Orange G.
SECTION, + 12 μ
PREPARED BY R. G. H.
DATE, 1905.
CONTAINERS. BOX 22
VALUE. $ 6.00
REMARKS
HELD IN 70 % AL 3 MO. BEFORE SECTIONING.
NOTE ON EYE NO. 347.
ON SCLEROTOME 566.

FIG. 1.

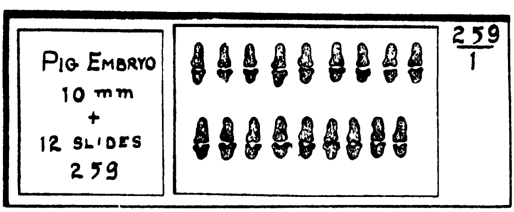


FIG. 2.

* One hypothetical case is followed through all the cards figured.

present a neat appearance, and have been found very satisfactory, not only for numbering museum jars, but slide boxes and carriers as well. They may be obtained in either black or red.

Should the embryo be sectioned, the slides upon which it is placed bear in the upper right-hand corner a fraction written with a diamond pencil (fig. 2). The upper number is the accession number of the embryo; the lower number indicates the position of the slide in the series of slides made from the particular embryo. This device, the credit for which belongs to Mr. R. G. Hoskins, former fellow to the department, insures the identity of each slide, and to a great extent prevents the loss of slides. The slides may also be labeled if desired. In this collection only the first slide of the series is labeled. The label is written in India ink on thin, tough paper, exactly the size of an ordinary square cover-glass, 22 mm. by 22 mm. This label is then soaked in creosote and mounted in balsam under a cover, in the same manner as a section might be. Such a label never fades or becomes detached from the slide, and is a great improvement over the old-fashioned paper label.

After experiments with a number of styles of containers, the boxes holding 100 slides and having about the dimensions of an ordinary quarto volume have been found the most satisfactory. Such containers are reasonable in price, and may be had of any of the well-known dealers in microscopical supplies. These boxes are serially numbered on the backs, and are placed on shelves, as books might be. A large card just fits into the lid of each box (fig. 3). This card is ruled off into three columns, in which are recorded the accession numbers, the number of slides, and a brief statement of the material of the sets contained in the box. Such cards are only slightly attached to the box lid, and may be removed if desired. The number of the box in which each set of slides is placed is noted, in pencil, in the "Container" space on the proper data card (see fig. 1). While no strict classification of the slides is attempted, because a slide may always be located from the data card, still a general classification of slides into large groups is possible, and will suffice for a long period without

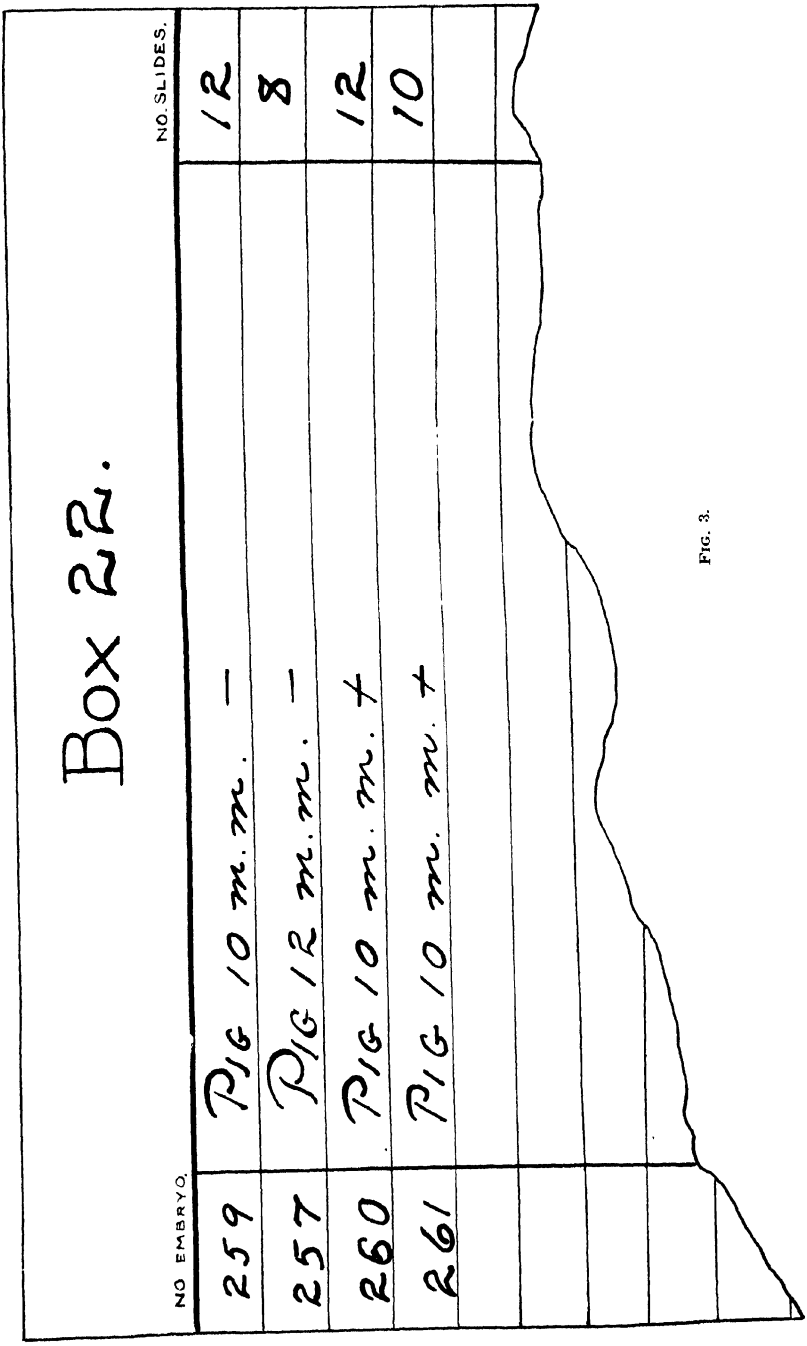

Box 22.
NO. EMBRYO.
NO. SLIDES.
259 Pig 10 m.m. — 12
257 Pig 12 m.m. — 8
260 Pig 10 m.m. + 12
261 Pig 10 m.m. + 10

FIG. 3.

readjustment. The boxes described above are the permanent receptacles for the collection of slides. When slides are issued for class use different styles of holders are employed. For single slides and small sets the pressed-cardboard containers manufactured by Theodore Schröter, of Leipzig, and carrying from four to six slides, are used. For larger sets, such, for example, as cross-sections of pig embryos, the improved whitewood boxes which hold twenty-five slides are quite satisfactory. Each container bears a number both on the box and on the lid. Upon issuing slides in a container a card such as is shown in figure 4 is made out. This gives the number of the container, the identification fraction of the slides therein, their value, and the box from which they were taken. It also bears the signature of the person or persons who may receive the container, together with the date and locker number. To fill out such a card takes but a moment, and after being signed it is held as a receipt until the material is returned. This system has stopped the loss of slides resulting from class use.

A separate set of cards is used for keeping a record of observations on the material in the collection. It is hoped that in the course of time this series of records will become of increasing value, not only as time-savers and in teaching, but also as aids to advanced work. To record such observations a special card such as is shown in figure 5 is used. A glance at the figure will explain it. The location readings are recorded in the right-hand column, and consist of the index fraction of the slide and the position of the section upon it. These cards are supplied to students sufficiently advanced to recognize phenomena of value, and are of material advantage to them in keeping an accurate record of their work. After being filled out, the cards are collected and classified according to the same general plan as are the literature cards in the *Concilium Bibliographicum*. The main divisions being:

Ovum.
Laminæ germinis et Embryo primordia.
Adnexa embryonis.
Histogenesis et Organogenesis.

NO		VALUE
35	from Box 22	$6.00

CONTAINING— 259.1 – 259.2 – 259.3 – 259.4.

DATE.		NO.	GROUP
Oct. 25, 06	P. L. Green	25	III
	The loss of one slide destroys half the value of the set.		

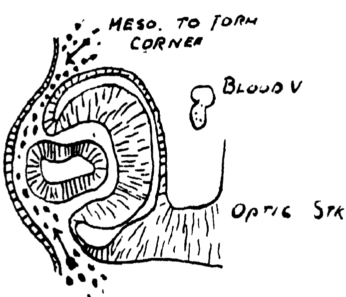
FIG. 4.

EMBRYO NO.	SYSTEM / STRUCTURE	CARD NO.
259	Organa sensum. Organon visus.	347

ANIMAL Pig + STAGE 10 m.m.

LOCATION: III 2, 3.

SHOWS FORMATION OF CORNEA + EXCENTRIC POSITION OF OPTIC STALK.



NOTED BY P. L. Green'd

FIG. 5.

Each of these main heads is subdivided. For the last and largest division, Barker's "Anatomical Terminology" (BNA) has been made use of as a general guide, although most of the minor headings have been omitted and the names of the more distinct embryonic structures have been interpolated where it seemed necessary. Thus the headings under heart (Cor), for example, are:

COR.
Epicardium.
Myocardium.
Endocardium.
Sinus veinosus.
Atria.
Ventricula.
Bulbus arteriosus.
Conus arteriosus.

Any other logical morphological classification would do as well. In order to classify the records according to the groups of animals, as well as the structures they represent, small celluloid riders which fasten on the upper edge of the card may be used, these riders to be of different colors—a color having been selected to represent each class of vertebrates; for example, red for Pisces and blue for Batrachia. It is only necessary to attach the properly tinted celluloid rider to each information card and an easy system of cross-indexing of notes is established.

When embryos are photographed, the plates are placed in envelopes bearing the photographic data and the number of the embryo. A specimen photograph is placed in a large scrap-book and the number and page are recorded on the original data card of the specimen.

DEPARTMENT OF ZOOLOGY,
UNIVERSITY OF KANSAS,
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SOME NEW FEATURES IN UINTACRINUS.

BY H. T. MARTIN.

Contribution from the Zoological Laboratory.

With plates IX and X.

THE morphological study of *Uintacrinus* by Mr. F. A. Bather, of the British Museum,[1] closely followed by the more elaborate memoir on this interesting crinoid by Mr. Frank Springer,[2] in which he so ably describes its relationships and structure, seemed to cover all the points that possibly could be brought to light on the subject. Nevertheless it is the intention in this paper to try to present some new features of the internal construction of the nerve grooves. These were first found on the inner surface of a single calyx in the writer's collection, and their presence confirmed by the examination of several specimens in the University collection.

When examining specimen No. 1, I found that in this particular instance the thin lenticular mass forming the plate, or slab, had been split by weathering and frost, from which I concluded that by splitting other plates some interesting features might possibly be shown. Accordingly a number of small weathered plates were experimented upon, and these amply repaid the effort, duplicating the appearances found in the first one, and strengthening the evidence upon several points shown on specimen No. 1.

Specimen No. 1 shows the inner floor of a nearly complete calyx (pl. IX, fig. 1) inverted and lying on its dorsal surface, thus exposing, for the first time, to my knowledge, the cup

1. On *Uintacrinus:* A Morphological Study. Proc. Zool. Soc. Lond., vol 1895, pp. 974-1004.

2. *Uintacrinus*, its Structure and Relations. Mem. Mus. Comp. Zool. Harvard Coll., vol. XXV, No. 1.

in this position. Hill[3] and Bather[4] both tried to obtain some idea of the internal construction by dissecting, and removing the plates, but with no success; while Bather says of the calyx, "the dorsal cup alone is known to us."

By referring to plate IX, figure 1, in which specimen No. 1 is shown natural size, it will be seen that the calyx was very little distorted by the flattening out, and that the base is nearly in the center of the specimen as preserved; and although incomplete it shows a base, dicyclic in form, composed of five basals, five very small, irregular infrabasals, and a centrale. Enough of the cup is preserved to show plainly the structure and course of the nerve strands from the outer margins of the basals to the second secundibrachs.

There is a well-defined grooved ring, pentagonal in shape, which joins together the nerve grooves that radiate from the basals at the center of the radials. (Pl. X, fig. 2.)

Specimen No. 1, plate IX, is the most instructive one examined, and shows the internal part of the calyx. This has a dicyclic base, with small, irregular infrabasals.

There are seven distinct but very small nerve grooves, three from each right and left half of the two adjoining basals, and a middle groove, a little the widest, which is in a direct line with each interbasal suture. A single groove, commencing at the basi-interradial suture, forking at the level of the basals, joins the set of grooves at the basi-radial suture, from where they all converge to a center in the middle of the radial plate, when they join the corners of the pentagonal ring commisure encircling the basals. The junctions of the radials are also connected at the sutures by four small grooves, two on each side of the ring commisure. The nerves leading up into the arms, as far as the primabrachs, are carried in four grooves (see pl. IX, fig. 2), which are encircled in shallow diamond-shaped pits, radiating from the pentagonal ring at the center of the radials. The pits containing the nerve cords must have been a receptacle for a bunch of muscular ligaments, having its main points of attachment at the center of the plates, the nerve cords follow-

3. Kan. Univ. Quart. 1894, vol. III, No. 1.

4. A Morphological Study of *Uintacrinus*, Proc. Zool. Soc. Lond., vol. 1895, p. 979.

ing the same line. The depressions are connected with each other by a narrow canal at the center of the plate it traverses.

The radial diameter of the proximal depression exceeds the transverse diameter by half its length, while exactly the opposite occurs at the point where the pinnules branch out (see pl. IX, fig. 3), until at the sixth and seventh secundibrachs they appear only as deep, narrow, transverse grooves which extend clear across the arm plates. Each series of pinnules is supplied with a set of the nerve groove depressions, which branch out from the main arm grooves.

The specimen on plate IX, figure 4, shows some well-defined markings on the inner side of the plates of a portion of another cup. The lines occur in three or four small terraces, which conform very regularly to the shape of each plate, and must have been for the attachment of several layers of ligamentary muscular tissue, thus forming a much stronger, though no less flexible sutural articulation than has been heretofore supposed probably.

Bather[5] says: "If the base be dicyclic, the ring forms a commisure at the level of the centers of the basals; and from these points the cords again fork towards the adjacent infrabasals, where they join in another ring round the chambered organ."

Out of the six specimens I have examined, all of which are dicyclic, four show a perfect ring commisure at the level of the radials; the other two show it distinctly on three of the radials. I have traced a single nerve-cord groove clear from the basi-infrabasal sutures to the center of the basals, at which point they fork, sending out a prong towards the center of each of two adjoining radials. From the above evidences of the course of the nerve-groove system, which appears to be directly in opposition to the principle laid down in Lancaster's Zoology, it would seem that some alteration must be made in our ideas of the course of the nerve groove and situation of the ring commisure in dicyclic forms, at least in the case of *Uintacrinus*.

A diagram based upon the material examined, showing the

5. Lancaster's Zoology, part III, p. 194.

probable course of the nerve grooves, is shown on plate X, figure 1.

I here wish to thank the following for the interest shown and assistance given in the preparation of this paper: Mr. Frank Springer, for many valuable suggestions; Dr. C. E. McClung, for much assistance and for the fine photographs, all of which he kindly made; and Miss Nadene Nowlin, for the drawings.

PLATE I.

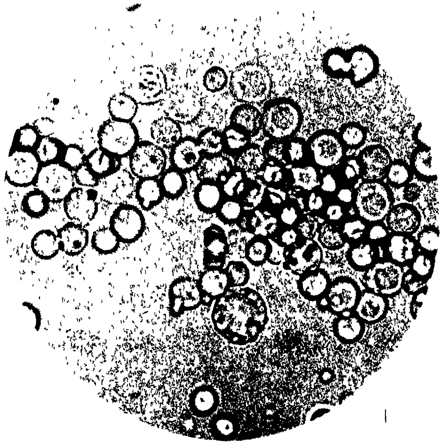
Saccharomyces anomalus grown in liquid media.

FIGURE 1.—The parent type from an old culture in wort.

FIGURE 2.—A new race of the same age grown in the same medium.

FIGURE 3.—A young culture of a new race grown in broth.

Plates I, II and III are magnified 1000 diameters; plate IV, 250 diameters. The yeasts represented in plate I were photographed unstained. Those in plate II were stained in an aqueous solution of neutral red, and the bacteria in plate III were stained with carbol fuchsin. Owing to shrinkage in staining, what were continuous filaments in the living culture of the bacteria often show as chains of disconnected elements in the photomicrograph (fig. 2, plate III). In all cases the new races and the corresponding parent races were stained alike and photographed with the same magnification. None of the photographs have been retouched in any way.



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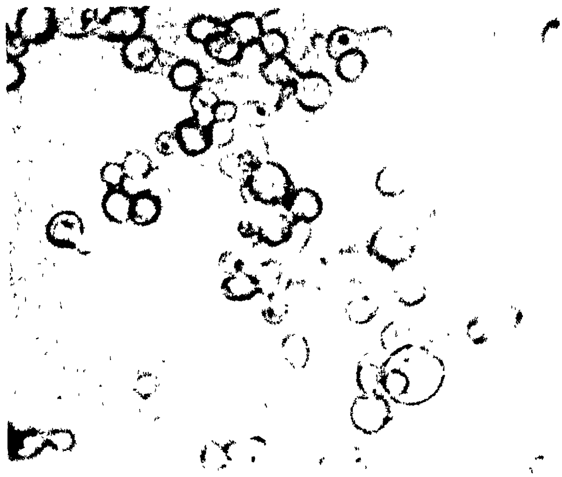

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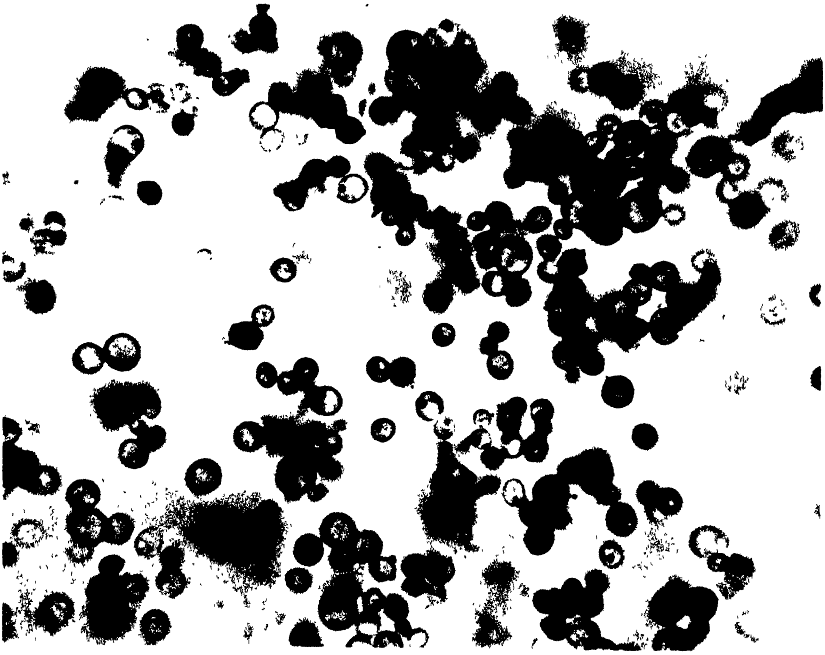
PLATE II.

Saccharomyces anomalus.

FIGURE 1.—The parent type after about ten days' growth on glucose agar.

FIGURE 2.—A new race grown on the same medium and under the same conditions as the parent. This new race had been originated two years and four months previously.



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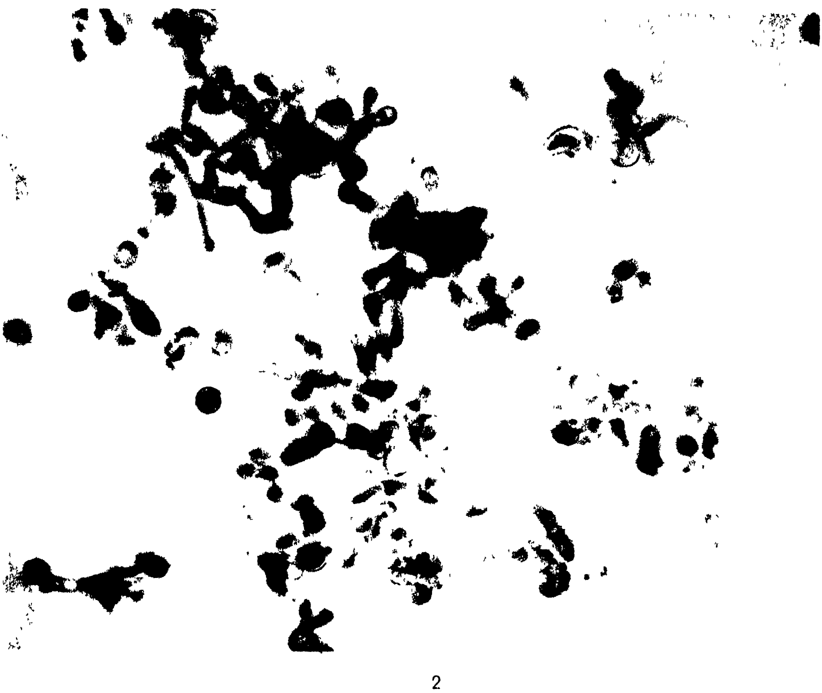


2

PLATE III.

Bacillus coli communis.

FIGURE 1.—Parent type from a one-day broth culture.

FIGURE 2.—New race A, grown under the same conditions.

1

2

PLATE IV.

Saccharomyces anomalus.

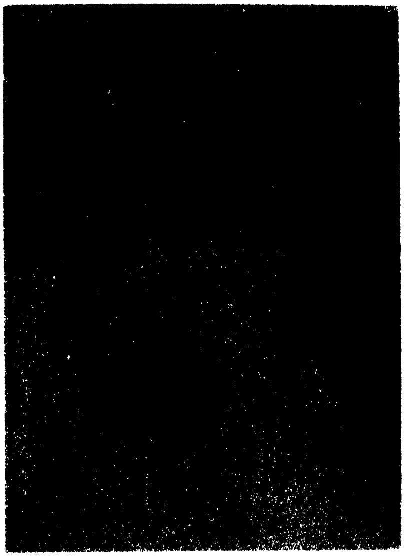
FIGURE 1.—Colonies of the parent type in glucose gelatin.

FIGURE 2.—Colonies of a new race grown under the same conditions. The new race colonies show a ragged outline, due to the outgrowth of elongated cells.

Bacillus coli communis.

FIGURE 3.—Colony of the parent type, grown in gelatin.

FIGURE 4.—A colony of the new race A, grown under like conditions.



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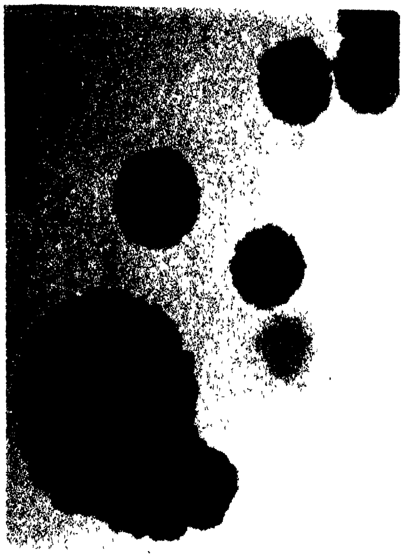

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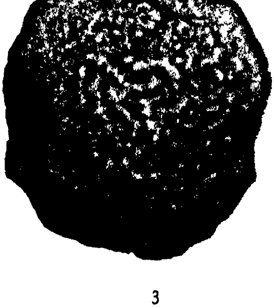

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PLATE V.

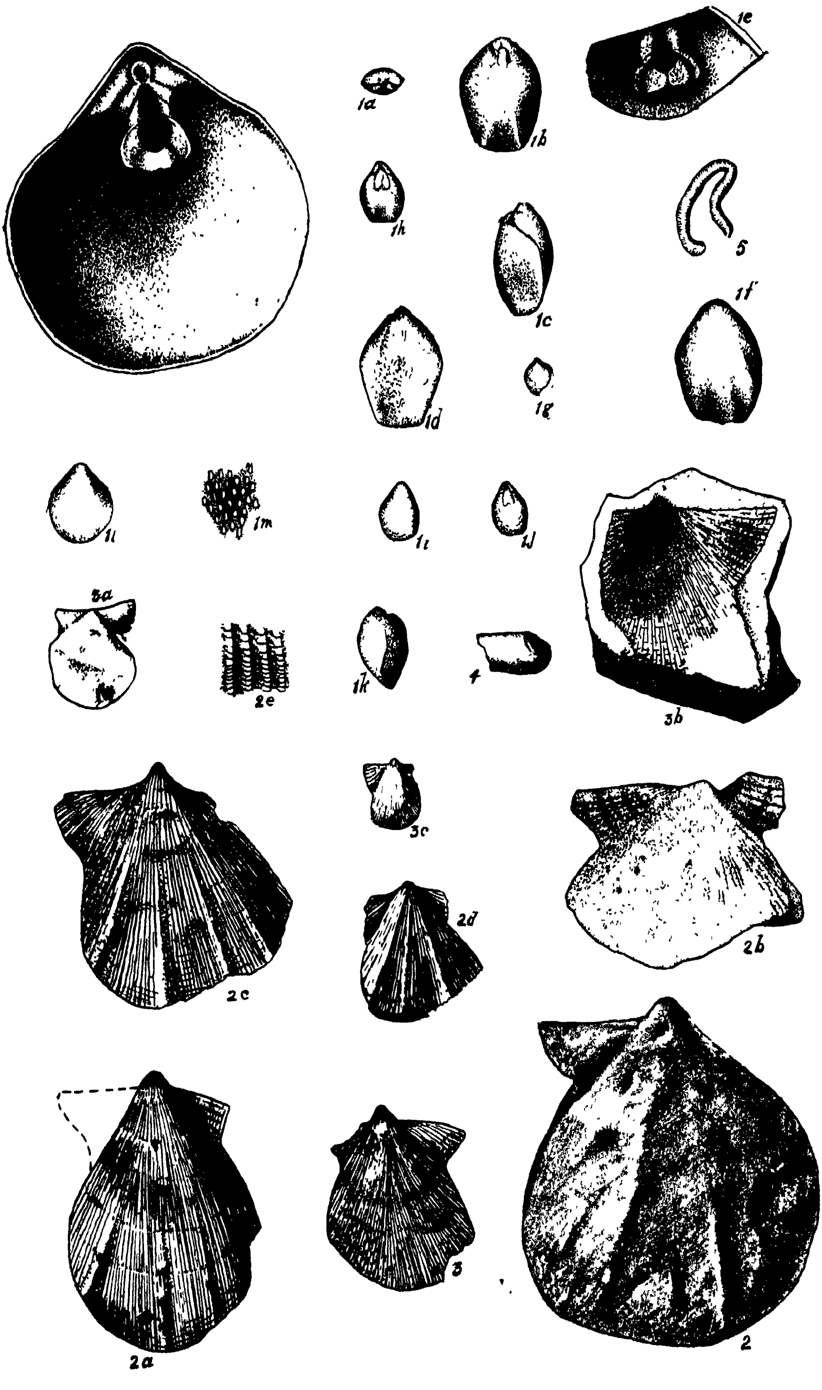


PLATE V.

Dielasma schucherti. Page 148.

1.—Interior of the shell of a young specimen, 5 mm. in length, showing loop, foramen, etc. The loop should be more angular where it begins its curve. No. 59 of collection from Dozier, Tex.

1*a*, 1*g*, 1*h*, 1*i*, 1*j*.—Young specimens, showing some of the variations in form, the muscular impressions (elevations in casts) in the shell which later fill to form a sort of platform. Most of the figures are a trifle over natural size; 1*h* shows the beginning of the plications. Sometimes the shells attain a much larger size before showing the plications as in 1*l*. Specimens Nos. 32, 30, 29, 28, 31, respectively, from Whitehorse spring, Oklahoma.

1*b*.—Adult specimen, brachial aspect, showing biplication, crural and lemellar impressions.

1*c*.—Side view of same; 1*d* is the pedicle view, showing impression of dental lamellæ. No. 25, Whitehorse collection.

1*e*.—Another specimen from Dozier, younger than 1, showing loop still disconnected. There is a more acute angle, than shown in the drawing, where the loop first rolls outward from the supports. No. 125, Dozier collection.

1*f*.—An abnormal specimen of pedicle valve showing a tendency to develop more plications and strong sets of dental lamellæ. No. 24, Whitehorse collection.

1*k*.—Lateral view of robust specimen, still immature.

1*l*.—A figure of a half-grown individual. No. 27, Whitehorse collection.

1*m*.—A portion of a replaced shell in a mold, showing the punctæ. Very highly magnified. Under an ordinary lens they appear as the ordinary meshwork of *Dielasma*. No. 23, Whitehorse collection.

Aviculopecten vanvleeti. Page 159.

2.—A very large, poorly preserved specimen. Natural size. No. 13 Whitehorse collection.

2*a*.—A somewhat smaller specimen, showing the nature of the surface marks and one of the ears. The drawings of this species are poor and express very inadequately the surface characters of the species. They are like those of *A. occidentalis*, but with three to five large ribs, more pronounced than in that species. No. 10, Whitehorse collection.

2*b*.—Broken opposite valve of another specimen probably of this species. It is remarkable in being almost free from surface marks. No. 17, Whitehorse collection.

2*c*.—A slightly flattened valve of this species showing the opposite ear from that shown in 2*a*. The figure shows the ear a little too convex and the sinus below it too shallow, changing considerably the expression of the shell. No. 11, Whitehorse collection.

(OVER)

2d.—A small broken shell of this species, showing portions of both ears. No. 14, Whitehorse collection.

2e.—A portion of the lower right side of *2a*, enlarged to show the nature of the surface ornamentation. No. 10, Whitehorse collection.

Aviculopecten oklahomaensis. Page 158.

3.—A rather small convex valve. The outline of the specimen is faulty, particularly the ear and anterior region. It shows, however, the fact that the ribs are all equal in size except those coming in by implantation. It differs somewhat in its umbonal region from the type figured on the following plate, and may possibly be a different species. No. 19, Whitehorse collection.

3a.—Flat valve, probably of this species, nearly complete, showing strong byssal sinus. No. 12, Whitehorse collection.

3b.—The mold of a valve somewhat larger than No. 3, showing the impressions, poorly, of the vaulted scales on the ears. No. 20, Whitehorse collec ion.

3c.—A young specimen of this species and a nearly perfect cast of the left valve. The anterior ear is shown a trifle too large, and the sinus below it a little too shallow, thus making the ear extend a little too far down the shell. Ventral outline more rounded than shown in the figure. No. 18, Whitehorse collection.

Solenomya sp. Page 150.

4.—View of right valve. One of the two specimens in the collection. No. 22, Whitehorse collection.

Serpula? sp. Page 148.

5.—A minute specimen shown in the mold of a shell. The length of the op of the specimen is little more than ½ mm. No. 126, Dozier collection.

PLATE VI.


1
2a
1a
1a
1d
3b
1b
3
1c
6
5
4
3d
2
4a
3c
7
8b
8d
9
8e
8c
8
10
8a
11
11a
11b
11c

PLATE VI.

Cyrtodontarca ? gouldii. Page 152.

1–1*c*.—Views of valves. 1 and 1*c* are right valves, 1*a* and 1*b* are right valves, all showing nature of dentition, as best it can be shown, under the beaks of the casts. The specimens are tilted at various angles to show the teeth, which accounts for the variety of peculiar forms.

1*c*.—Appearance of right valve showing two lateral teeth. Nos. 69, 68, 52, 54, and 70, respectively, of Whitehorse collection.

2, 2*a*.—Specimens referred provisionally to this species, though they are probably distinct from it. 2*a* shows the dentition. Nos. 50 and 51, Whitehorse collection.

Cyrtodontarca ? parallelidentata. Page 153.

3–3*c*.—Four specimens of this species. No. 3 shows the general aspect of the cast of the shell, somewhat broken; 3*a* and 3*b*, two right valves enlarged, showing, poorly, the nature of the dentition; 3*c* is the left valve, showing the dentition much better. Enlarged. Whitehorse collection.

Cyrtodontarca ? multidentata. Page 153.

4, 4*a*.—Left and right valves, showing dentition. Enlarged. Nos. 55 and 56, Whitehorse collection.

Cyrtodontarca ? sp.

5.—A specimen, the dentition of which is not preserved, showing the nature of the surface markings. $\times 3/2$. No. 101, Whitehorse collection.

Cyrtodontarca ? sp.

6.—An incomplete specimen, dentition not shown. No. 55*a*, Whitehorse collection.

Myalina sp. Page 156.

7.—Fragment of valve, natural size. No. 74, Whitehorse collection.

Pleurophorus ? albequus. Page 160.

8.—Left valve of specimen, showing radiating ribs and a strong, more backward-curving ridge in the shell than normal, with correspondingly sharp beak. No. 42, Whitehorse collection.

8*a*.—Right valve of a young specimen, possibly of the variety *longus* of this species, showing lateral posterior hinge tooth. No. 41, Whitehorse collection.

8*b*.—Enlarged beak of left valve of cast, showing impression of hinge

(OVER)

teeth. The posterior of this specimen (not figured) has the lateral tooth parallel with the hinge strongly developed. No. 39, Whitehorse collection.

8*c*.—Right valve of a specimen, showing only two radiating ridges. No. 38, Whitehorse collection.

8*d*.—Squeeze from mold of right valve of specimen, with beak and hinge line missing, showing five ridges.

8*e*.—The mold of the above specimen, showing lamellar striæ in the sinus below the umbo and the impressions of the "granulations" below the beak. No. 58, Dozier collection.

Pleurophorus albequus longus. Page 162.

9.—Cast of right valve. Front and posterior end broken away. No. 40, Whitehorse collection.

Spirorbis sp. Page 148.

10.—View of cast of attached surface shown on cast of a shell. Greatly magnified. No. 44, Whitehorse collection.

Aviculopecten oklahomaensis.

11.—A somewhat broken specimen of a left valve, about natural size. No. 21, Whitehorse collection.

11*a*.—Another individual, probably compressed antero-posteriorly, making the beak appear narrower and sharper than it should. There is also a slight difference in the size of the ribs and the concentric markings are not brought out so strongly as they should be in the drawing. No. 16, Whitehorse collection.

11*b*.—Mold of a small specimen; 11*c* is a rough squeeze of the same enlarged, showing the undulating striæ sometimes found upon specimens of this species. No. 15, Whitehorse collection.

PLATE VII.

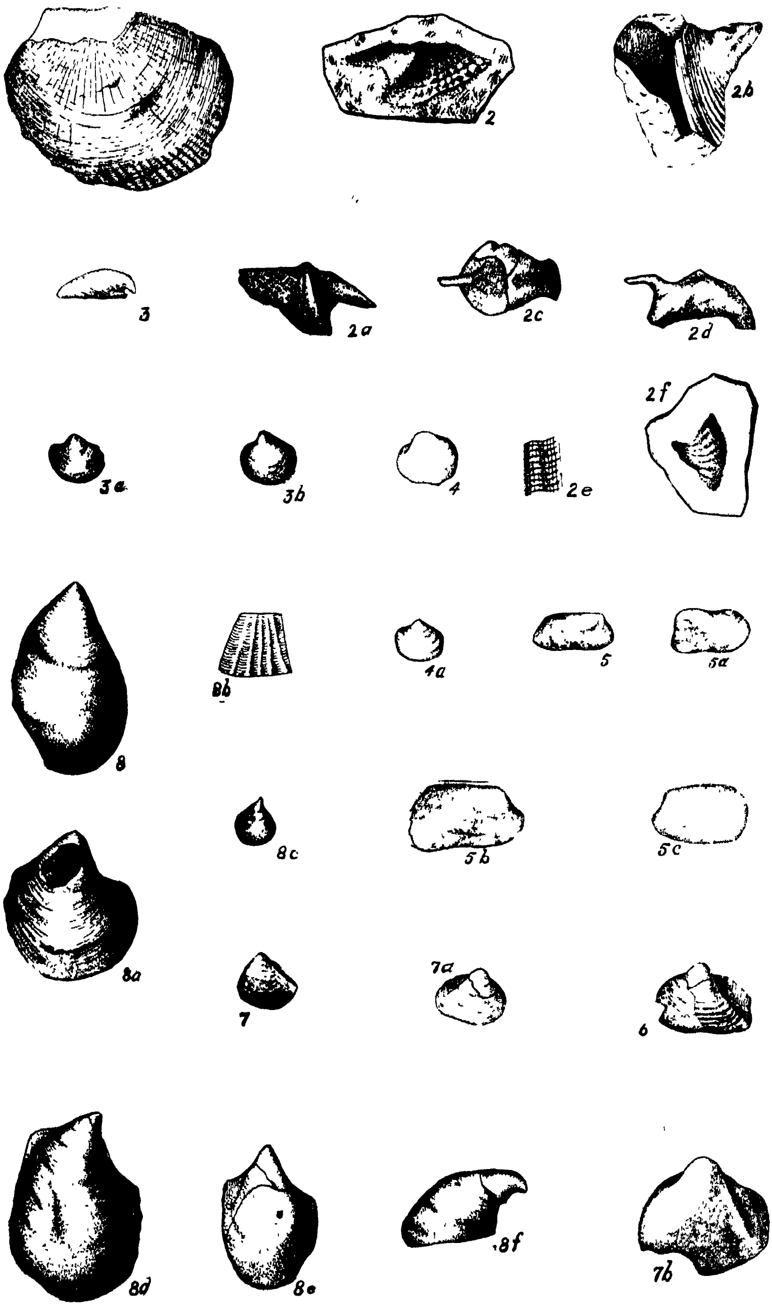


PLATE VII.

Pseudomonotis sp. Page 156.

1.—Portion of flat valve, natural size. No. 103, Whitehorse collection.

Conocardium oklahomaense. Page 151.

2.—Mold of a specimen, about natural size.

2*a*.—Squeeze of the same. No. 33, Whitehorse collection.

2*b*.—Drawing of a fragmentary specimen, greatly enlarged, to show the markings on the posterior of the shell. No. 35, Whitehorse collection.

2*c*.—Vertical view of a cast.

2*d*.—Lateral view of same. No. 36, Whitehorse collection.

2*e*.—Greatly enlarged portion of the mold of another specimen, to show the fine markings on the umbonal keel. No. 34, Whitehorse collection.

2*f*.—A portion of the mold of another specimen, enlarged, showing the larger longitudinal ridges on the posterior portion of the shell. No. 37, Whitehorse collection.

Edmondia rotunda. Page 150.

3.—Profile of cast, showing slit formerly occupied by the platform beneath the beak, characteristic of the genus. Enlarged. No. 75, Whitehorse collection.

3*a*.—Left valve of same, natural size.

3*b*.—Left valve of another specimen. No. 76, Whitehorse collection.

Edmondia cumminsi. Page 151.

4.—Cast of type specimen, natural size. No. 57, Dozier collection.

4*a*.—Another specimen, natural size. No. 104, Dozier collection.

Allorisma? albequus. Page 160.

5.—Cast of right valve, $\times 2/1$. No. 105, Whitehorse collection.

5*a*.—Cast of left valve, $\times 2/1$. No. 106, Whitehorse collection.

5*b*.—Cast of right valve, from Texas, $\times 2/1$. No. 55*a*, Dozier collection.

5*c*.—Cast of left valve, $\times 2/1$. No. 55, Dozier collection.

Schizodus? oklahomaensis. Page 157.

6.—Cast of valves, natural size. No. 46, Whitehorse collection.

Schizodus ovatus?. Page 157.

7.—Cast of left valve, imperfect in posterior outline, natural size. No. 8, Whitehorse collection.

(OVER)

7a.—Cast of right valve of another specimen, natural size. No. 7, Whitehorse collection.

7b.—Cast of left valve of a large specimen, poorly preserved, probably of this species, natural size. No. 6, Whitehorse collection.

Capulus sellardsi. Page 170.

8.—Cast of a large, rather narrow specimen, dorsal view, natural size. No. 4, Whithorse collection.

8a.—Same view of another individual, broad form, natural size. No. 2, Whitehorse collection.

8b.—Enlargement of surface detail from posterior, right part of *8a.*

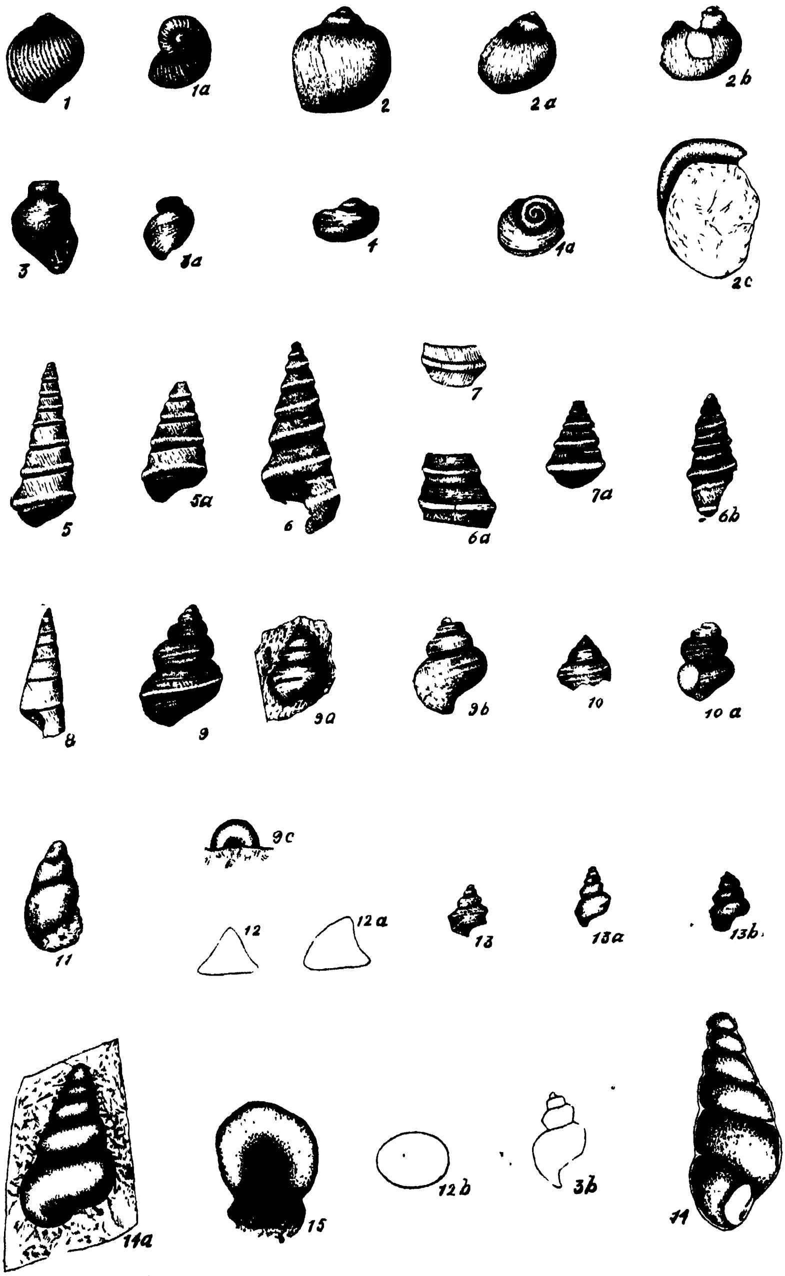
8c.—A young specimen of this species, natural size. No. 5, Whitehorse collection.

8d.—Dorsal view of intermediate form, natural size. No. 3, Whitehorse collection.

8e.—Dorsal view of the type specimen, a cast, natural size. No. 1, Whitehorse collection.

8f.—Lateral view of *8e.*

PLATE VIII.



1
1a
2
2a
2b
3
3a
4
4a
2c
5
5a
6
7
6a
7a
6b
8
9
9a
9b
10
10 a
9c
11
12
12 a
13
13a
13b
14a
15
12b
3b
14

PLATE VIII.

Naticella transversa. Page 171.

1, 1*a*.—Vertical and lateral views of a specimen enlarged about three diameters. From a squeeze. No. 6, Dozier collection.

Strophostylus permianus. Page 170.

2.—A large specimen, showing growth lines.

2*a*.—Another specimen, somewhat distorted, natural size. No. 71, Whitehorse collection.

2*b*.—Another compressed individual, enlarged. No. 72, Whitehorse collection.

2*c*.—Base of another specimen, showing aperture. No. 102, Whitehorse collection.

Trepospira haworthi. Page 166.

3.—Specimen showing approximate form of the apertures as shown in section of body whorl near the mouth of the shell, in the matrix. Enlarged. No. 59, Whitehorse collection.

3*a*.—Another individual, showing body whorl. Enlarged. No. 62, Whitehorse collection.

3*b*.—Outline of another specimen, showing spire. Enlarged. No. 63, Whitehorse collection.

Worthenopsis depressa. Page 164.

4.—Lateral view of specimen, natural size.

4*a*.—Nearly vertical view of the same. No. 45, Whitehorse collection.

Orthonema? texana. Page 168.

5.—Squeeze of specimen, showing general form of the shell. No. 1, Dozier collection.

5*a*.—Squeeze of a diagonal section of a mold which makes the shell appear too obtuse. No. 2, Dozier collection.

Murchisonia gouldii. Page 167.

6.—Lateral view of squeeze, enlarged about two and a half times. No. 14, Dozier collection.

6*a*.—Enlargement of same, showing surface marks.

6*b*.—Another individual.

Murchisonia collingsworthensis. Page 166.

7.—A detailed enlargement of the mold from which the squeeze shown in the following figure was taken.

7*a*.—View of squeeze, showing form of spire. No. 36, Dozier collection.

(OVER)

Orthonema dozierensis. Page 168.

8.—Lateral view of squeeze, $\times 5/1$. No. 7, Dozier collection.

Pleurotomaria capertoni. Page 168.

9.—Squeeze of type. No. 5, Dozier collection.

9*a*, 9*b*.—Two specimens of this species from Whitehorse sandstone.

9*c*.—Basal view of 9*a*, showing closed(?) umbilicus. Nos. 77, 78, Dozier collection.

10, 10*a*.—Two specimens possibly belonging to this species, but probably distinct. The latter is somewhat distorted. Nos. 22, 23, respectively, Dozier collection.

Bulimorpha? alvaensis. Page 169.

11.—Side view of cast, natural size. No. 64, Whitehorse collection.

Capulus? haworthi. Page 169.

12, 12*a*, 12*b*.—Outlines of an apical and two lateral views. Two specimens. Nos. 31, 32, respectively, Dozier collection.

Worthenopsis sp. Page 165.

13.—Drawing of a squeeze, enlarged. No. 39, Dozier collection.

Pleurotomaria agnostica. Page 164.

13*a*, 13*b*.—Two casts, poorly preserved, enlarged. Nos. 73, 65, Whitehorse collection.

Loxonema permiana. Page 167.

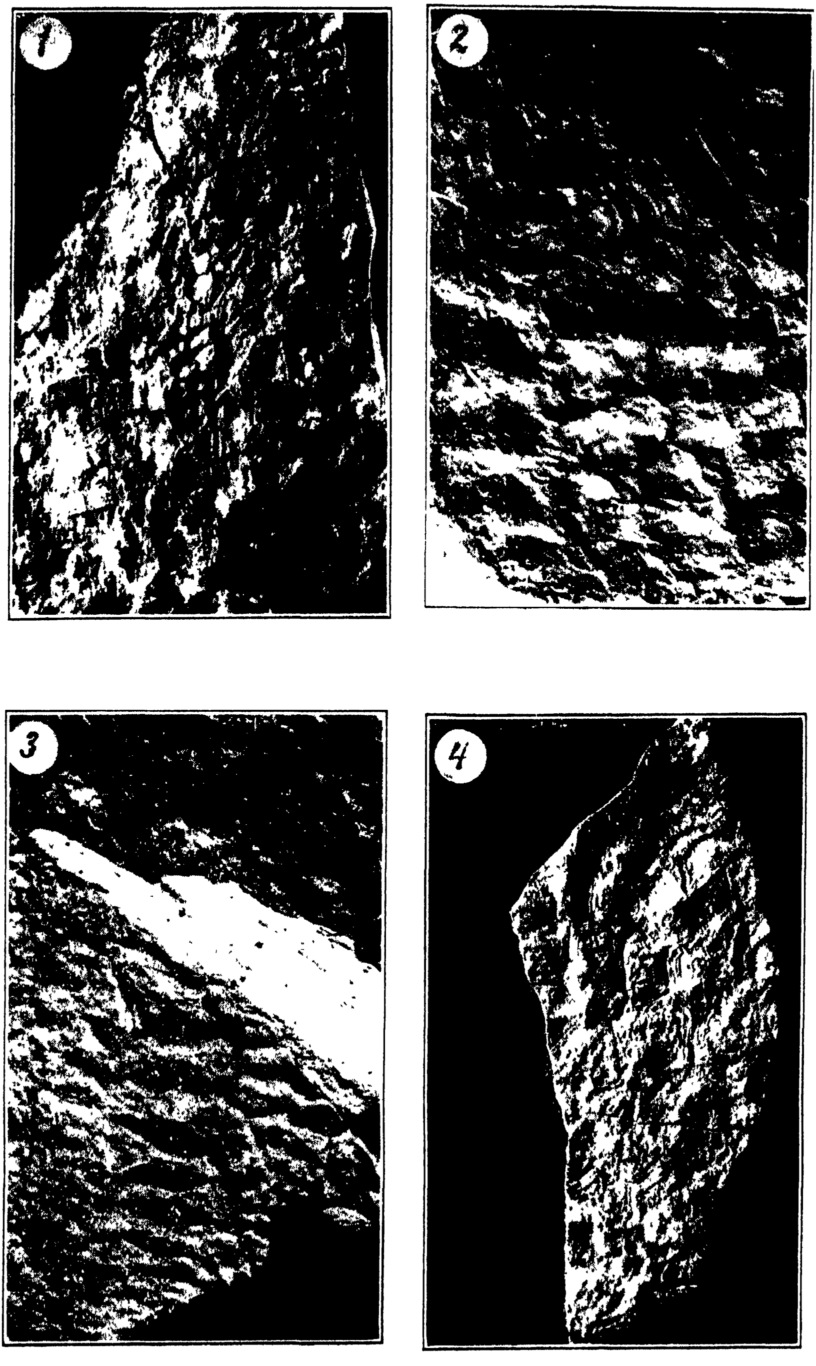
14.—Mold of specimen, $\times 19/2$. No. 12, Dozier collection.

14*a*.—A section of a mold, somewhat diagonal, of another specimen. No. 13, Dozier collection.

Pleurotomaria sp.

15.—Basal view of cast, showing a sheet of matrix extending into the umbilicus, demonstrating the existence of an umbilical slit. This species is probably generically distinct from No. 9*c* on this plate. Unfortunately this specimen was dropped and the matrix broken out after the drawing was made. No. 66, Whitehorse collection.

PLATE IX.



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CYTOLOGY AND TAXONOMY.

BY C. E. McCLUNG.*

(Contribution from the Zoölogical Laboratory, No. 174.)

THERE are certain large problems in the domain of biology that confronted the earliest investigators, and these have been handed down from one generation of scientists to another. As new and more restricted departments separated themselves from the older and more general ones they carried with them these same problems, toward the solution of which they applied their own special methods, giving them at the same time something of their own bias. Very prominent among these great questions, and, in a measure, at least, embracing them all, are those which concern the relation of organisms to each other, and the processes of development in the individual organism.

To the youngest of the biological sciences have descended these heritages of the scientific ages, and now we hear it from many sources that all biological problems are to-day problems of the cell. Clearly enough it has been recognized that cytology might have much to say regarding the mechanism of ontogenetic growth, but less definitely, and only more recently, has a conception of what it might do for phylogeny arisen in the minds of biologists. It was with the thought of these two functions of cytology in mind that I chose the somewhat indefinite title for this paper. I cannot but believe that cytology will honorably fulfil the obligations that science has placed upon it, and I feel that it is indeed a privilege to stand before you and call to your attention what our young department has already been able to accomplish, and to suggest possibilities for further usefulness.

* An address delivered before the section on Cytology and Heredity of the Seventh International Zoological Congress, at Boston, August 20, 1907.

It is with no desire to magnify my own humble part in the attack upon these problems that I make mention of the manner in which they have presented themselves to me. I have thought that by means of a concrete example I might perhaps more clearly exhibit the grounds for my theoretical beliefs and the reasons for the faith that is within me. I shall therefore first indicate the main features of parallelism between germ-cell structure and taxonomic relations that have appeared from investigations upon certain orthopteran species and then attempt explanations of the causal connections between the two sets of phenomena in the light of our present general knowledge.

From the study of a large number of saltatorial orthopteran species it appeared that the normal numbers of chromosomes in the males fell, in general, into two groups of twenty-three and thirty-three respectively. To a cytologist this was a very suggestive fact, for it indicated a precision in the organization of cells that was in advance of anything that had before been imagined. It was doubly interesting to note the opinions of orthopteran taxonomists with regard to the relationships of these species and to discover that they had segregated them into definite corresponding groups which are called "families." Merely as the result of the study I had made of the germ-cells, I would have classified these insects into two groups, one having a complex of twenty-three chromosomes and the other of thirty-three. On the other hand, many taxonomists, from careful and minute examination of the external anatomy of these same species, had agreed in placing them into family groups, which they call the "*Acrididæ*" and "*Locustidæ.*" Now, these families are clearly distinguished apart by ordinary taxonomic features, and to speak of the "short-horned" and "long-horned" grasshoppers is to summon before the mind of one acquainted with the animals very definite types of structure. And yet the distinction between these insect families is no more apparent to me from an inspection of the gross anatomy than it is from a study of the germ-cells. The possession of a complex of twenty-three chromosomes is just as typical an acridian character as is that of short antennæ. I do not regard it any argument against this cytological means of discrimination to learn that other than acridian organisms have twenty-three chromosomes, for so do other animals have short antennæ.

Clearly enough, it would seem, we have here an indication of

the great precision in organization so long inferred for the germ-cells. Were our knowledge more extensive we should doubtless see yet further evidences of this—and certainly it is our duty to seek them out—but for the present we must make use of this suggestive fact and learn from it what we may. The most important conclusion that can be drawn is that these chromosomes are primary factors in the mechanism of development, for no other structures of the cell exhibit any such constancy and definiteness of organization to parallel the structural differences of the resulting animals. Since they occur in the same number throughout the family, and since the end result of their changes is essentially the same in every case, they must be individually alike in each complex. Further, it may be concluded that always their functions for any given period in ontogenesis are the same. With this as a beginning it becomes a reasonable hope that we may attempt an analysis of the processes of organic development by associating modifications of the acridian type of body with variations in the chromosome complex of their germ-cells. In other words, the task of the cytologist engaged in the study of this group is to learn the history of the individual chromosomes and to associate this knowledge with what is known regarding the development of somatic structures.

This is obviously no light task, but, on the other hand, I do not consider it an impossible one. Fortunately, the chromosomes of different species have individual peculiarities in size, shape and behavior that make it possible to identify many of them without difficulty. Whether it will be possible to homologise them throughout the family is not, of course, nearly so certain. Such an extensive and thoroughgoing attack upon the problem may, however, not be entirely necessary. It may be sufficient to attempt an analysis of a more limited group than the family. In that hope a great many genera have been studied in order to find striking peculiarities that might assist in the establishment of relationships between chromosomes and somatic characters. The work has thus, for a time, been narrowed down to a few forms; and since my desire in this paper is not to give detailed results, but rather to point out the direction in which, I believe, work of this character should proceed, and to indicate the essential nature of my conclusions, I will briefly describe the conditions of the investigation at the present time.

Students of the Orthoptera have divided the family *Acrididæ* into nine subfamilies, of which only four are found in the United States. Material from these four has been studied, and I feel convinced that one of these subfamilies should be removed from the group. The other three are manifestly related, and so closely do two of them grade together that there is much dispute as to the disposition of certain genera. The third subfamily is definitely marked, and it is sufficient for the systematist to find a distinct spine on the prosternum of an acridian in order to place it in the subfamily *Acridiinæ.* Within this division of the family there are a large number of subgroups, the principal one being the Melanopli. This includes many extensive genera, of which one, *Melanoplus,* contains over 120 species in the United States. Another genus of this group, *Hesperotettix,* is of wide distribution but embraces only seven species. Of these latter I have studied three and they seem to be plainly marked in their body characters. I have thought that, by selecting a variable genus and another of the same group that is more stable, it might be possible to determine the general nature of the changes associated with variability. Both of these lines of investigation are being pursued, but it seemed best to consider first the nature of the less variable form, particularly since there is one chromosome that can definitely be identified throughout the genus.

This latter circumstance I consider extremely fortunate, for the occurrence of the same number of chromosomes within the family raises the presumption that they are serially homologous almost to a certainty; the discovery of the same element in three species of a certain genus amounts to a positive proof of this fact. Particularly is this true when it is understood that the homologous elements really represent two of the chromosome complex. With this definite structure indubitably marked in the different species, I felt that I had opened up before me an opportunity of unusual promise, but one which would require long and tedious labor for its development. I regret that more has not been accomplished, but what has been done is sufficient to indicate the fruitfulness of the investigation.

Briefly, then, we may note that, so far as our observations have gone, all the species of the genus *Hesperotettix* have within their first spermatocytes a multiple chromosome, a hexad, consisting of the accessory chromosome and one of the

tetrads. This is a generic character, one of those that serve to distinguish the group that taxonomists have called *Hesperotettix* from other members of the family *Acrididæ*. With my present knowledge I would feel safe, if I found an acridian cell containing such an element, in ascribing its source to the genus *Hesperotettix*. I should have as little doubt regarding its distinctive character as I should have regarding that of the animal from which it came. So far as I have been able to see, there is no other character of the cell that would distinguish this genus from the remaining ones of the *Acrididæ*.

Then it became necessary to see if there were peculiarities that bore any constant relation to body characters of specific value. It was most interesting to find that the multiple chromosome, so constant a generic character, should exhibit just as constantly minor modifications of size and proportion in the different species. This particular chromatic element therefore signifies to my mind as definite an integration of substance as does the adult animal which contained it. The differences between the same element in the three forms of *Hesperotettix* studied are just as specific as any that might be chosen from somatic characters. It would perhaps be well to say that I have made most careful comparisons in the size of these chromosomes, and it is very remarkable to find the extremely close concordance that exists within the species. If this is true of the fixed material which has been subjected to all the violent processes incident to the preparation of slides, how much more true it must be for the living object.

There are thus within the germ-cells of these animals certain structures that show specific, generic, and family characters in just as pronounced a manner as do the completed organisms wherein they are found. It is therefore desirable to know what corroboration we have from the study of other organisms for our belief in the great importance of the chromosomes. I would ask you, therefore, to review with me very briefly a series of facts which cytology, normal and experimental, has brought forth in support of the idea that the chromatin is the guiding and controlling element in development, and that the chromosomes represent definite centers of influence.

In the first place, organisms without chromatin do not exist, and when the nucleus is removed from an individual the normal functions cease. The necessity of the chromatin in the economy of the cell is thus proved. Next we may note that the

integration of the chromatin is always into a definite number of chromosomes in the individual, in the species, and sometimes in an entire family. From this the precision of organization inherent in the chromatin may be inferred. Again, throughout all the complications of the mitotic division every effort is apparently put forth by the cell to secure an accurate division of the chromatin. This suggests the primary importance of the chromatin and hints strongly of differential organization.

If now we turn from cells in general to the special category of germ-cells we find very much more evidence for our belief that the chromosomes are the determinants of characters and that they are qualitatively different. From this source we learn that normally, for the production of a new organism, two cells are required, and that the only feature of equivalence between them is in the chromosome complex, which in each case is a duplicate of the other. Not only are these morphologically equivalent groups of chromosomes, but they are also physiologically equal, for either complex alone may condition development in the same way, as is shown by parthenogenesis and merogony. Further evidence of this independence and equivalence of the chromosomes is furnished by the history of the cells of which they are a part, for step by step they go through the same preparation of maturation, and the particulars wherein they show resemblances are always those of chromosome behavior, no matter how much the other elements of the cell may differ.

While either the paternal or maternal chromosome complex in a cell is sufficient to condition the development of all the characters of the organism, the absence of any one chromosome of the group results in the non-development of some body characters. Such, at least, seems to be the conclusion that must be drawn from the work upon polyspermized eggs. It therefore appears very probable that the chromosomes are qualitatively different. Very strong additional evidence to support the view that the chromosomes *are* qualitatively different, and a duplicate series when present in the normal number, is afforded by the parallelism between the behavior of the chromosomes in maturation and fertilization, and the segregation of Mendelian characters in hybrids.

Let it be granted from the facts adduced that the chromosomes are the controlling factors in development, then how can we explain their action, how correlate them individually with

the somatic characters, and how explain their differences in the formation of body-cells and germ-cells from the same fertilized egg? Here we have the problem of heredity stated in cytological terms, and any theory offered in explanation must conform itself to the known facts. I am of the opinion that in our work upon the classification of organisms we have been much inclined to regard only the end stage of the process of development. A starfish has not been for us a starfish until it has acquired its radial symmetry and its adult organs. I believe that in this we are mistaken. The egg of the starfish performs its functions in just as specific a manner, and differs from the egg of a sea-urchin as truly, as do these same organisms differ after a few weeks of development. We must realize that an organism functions from its very beginning and that it does this differently from any other individual. We may not now be able to perceive these differences of individuals in the one-celled condition so clearly as we do when they are many-celled, but this is due to our lack of knowledge and not to the absence of variation. That one cell is sufficient for the identification of the species is clear enough from my study of *Hesperotettix* and other Orthoptera.

We must indeed recognize that organisms are specifically different throughout their ontogeny, and that they exhibit the functions of protoplasm specifically in every case—not one function, but all of them. It would accordingly be as difficult to add sex to an animal at some late stage of development as it would be for the egg starfish to change into an adult sea-urchin. The organization is inherent in the individual from the beginning; its method of expression differs, however, from stage to stage. Therefore we must conclude that the parts of the whole also differ progressively. Perception, movement, metabolism and reproduction are functions of the one cell just as truly as they are of the multitude of cells that results from its division.

If chromosomes are centers of influence governing always the manifestation of specific energies, then they must at every stage of development, both ontogenetic and phylogenetic, exhibit the same properties. In so doing they show themselves subject to the same laws of change that obtain in the differentiation of cells, for the nature and extent of their influence vary progressively. I think it is reasonable to conclude thus, for, if our assumption regarding the sex-determining nature of the accessory chromosome be correct, this is just what we

find to be true regarding the development of the sexual characteristics which are inherent in every cell of the body, and become progressively different in each state of development.

It is hardly necessary to say that no true student of cellular phenomena regards the chromosomes as the *only* factor in development. They play their part in the economy of the cell and accomplish thėir work solely because they exist under certain conditions. They appear to us as more definite and constant features of cell architecture than any others, and in their behavior exhibit such indications of initiative and importance as to lead to the belief that theirs is a directive action. Differentiation is regarded as a progressively changing series of interactions between the chromosomes and other parts of the cell, of such a nature that the nucleus initiates changes which are limited by the conditions of the cytoplasm.

In order that we may gain some idea of the possible nature of these interactions, I would ask you to consider with me certain phenomena that are observable in the development of the male germ-cells. Studies on spermatogenesis usually begin with a consideration of the spermatogonia, since these are the first cells found in a definite sexual organ, but there is little doubt that these are the last of a line of pure germ-cells that have been set off early in the embryonic history. These spermatogonia have the paternal and maternal chromosomes present in the same relations as exist at the time of fertilization. They divide rapidly and continuously until they become much decreased in size and almost the entire cell is nucleus. The cytoplasm is reduced to a minimum, but the nucleus, at least so far as the chromosomes are concerned, has not been much altered. In the grasshoppers, I feel convinced that the number of these divisions is, for each species, a constant. The reduction of the cytoplasm does not go beyond a certain point, and the process is self-limiting.

At this point conditions change. The members of the chromosome group, instead of remaining separate, as heretofore, unite in pairs, the components of which are size equivalents, and in all probability functional equivalents, from the two parents. This step is one toward which the chromosomes seem to have been tending during the later spermatogonial divisions, and one which certain elements anticipate in some species. There is every reason to suppose that this synapsis is a union of homologous elements, and is the consum-

mation of the fertilization process, initiated by the union of the spermatozoon and the ovum and rendered more intimate by the fusion of the nuclei. There is not entire agreement among observers regarding the exact time of the synapsis of the chromosomes, but it is always described as occurring between the last spermatogonial division and the first spermatocyte mitosis. In the grasshopper it is the final act of the spermatogonial chromosomes, and precedes the changes of the growth period. I am inclined to believe that it necessarily does so.

This act of synapsis is one that occurs only in the germ-cells, and to me it has always seemed of the utmost importance. Let us consider the conditions of the process a little more fully, and see if something of value may not be gained in our search for the cause of differentiation. The primordial germ-cells have been more or less intimately a part of the body. Their double sets of chromosomes have been functioning individually, if not even antagonistically, and have built up cell-bodies of considerable size. These early germ-cells are then gathered together in a single place and are thereupon removed from so intimate relations with the somatic cells. Under these conditions, as we have noticed, they reproduce rapidly with constant decrease in the amount of cytoplasm and end up with cells almost entirely nuclear in proportion and strongly chromatic. Here division ceases and the opposing paternal and maternal chromosomes, their cytoplasmic environment practically gone, unite together in synapsis.

Conditions are evidently ripe for a change. The change becomes apparent in an altered behavior of the cell, which, no longer expending its energies in reproduction, grows enormously both in nucleus and cytosome. Reproduction has given place to constructive metabolism. This is, however, such a metabolism as finds expression nowhere else in the life-cycle of organisms. Morphologically, at least, it accompanies a condition in which the paternal and maternal chromosomes are reduced to common units. Physiologically, I believe, it is a state wherein the chromosomes, having passed through many generations of cells in a cytoplasmic environment peculiar to the particular organism of which they are members, and having possibly exhausted the metabolic resources of these conditions, unite their common energies and construct a new cytoplasm. The extent of this growth varies with the species, but in every case is con-

siderable, and is accompanied, or rather preceded, by a corresponding nuclear enlargement. This growth in the case of the ovum is much more extensive, including the formation of all the varieties of differentiated "stuffs," but takes place under similar conditions. In both sexes this unique state of the cell is terminated by two mitoses, one of which witnesses the separation of the paired homologous chromosomes and their distribution into different cells. This, in reality, is the beginning of a new individual, for here are new conditions throughout the cell. It seems possible to me, in the light of our present knowledge of animal development, to gain some idea of the general nature of the phenomena involved in maturation and fertilization, and to grasp something of the meaning of the cell changes that take place at these periods. Clearly enough, in maturation there is a separation of chromosomes and in fertilization a restoration to the normal number. These alternately joined and separated chromosome groups are of different sexual origin and distribution, but are themselves without sexual characters, for in one generation they may be in a male organism and in the next in a female.

But when we have recorded these important facts we have by no means exhausted our knowledge of the difference between the immature and mature germ-cell. Much important work has been done within recent years upon the organization of the egg, and it has been clearly demonstrated that this is of a high order of complexity. The recognition of different "stuffs" in the egg, and the discovery that they are of various organ-forming powers, show most clearly that our theories of development must take the cytoplasm into due consideration. Such a recognition awarded cytoplasmic localization lessens in no measure the importance of the chromosomes, a fact that has been appreciated by none more clearly than by those who are most familiar with egg organization. Experimentally it has been proved that these particular materials are able to develop the earlier stages of the embryo without cell formation or nuclear division; and yet those who have most knowledge of such processes do not minimize the importance of the chromosomes, even though it may be granted that the cytoplasm has much to do with conditioning the early stages of development. Nor does the additional fact that the final stages of somatic differentiation are characterized by the preeminence of the cytoplasm weaken our belief in the primary importance of the chro-

mosomes. I think that a reconciliation of the apparently contradictory facts of cytoplasmic localization and chromosome control is not at all impossible.

There is but one time in the history of an organism when the production and arrangement of these specific materials occur; there is but one time when the biparental chromosomes function in common and not as separate entities. These periods are coincident, and I cannot escape the conviction that they are related as effect to cause. We find the spermatogonia and oogonia reduced by repeated divisions to an almost acytoplasmic condition, and at that point discover the chromosomes pairing off. During a long period of association, in certain grasshoppers extending through the winter months, these chromosomes remain together, and, at the end, present themselves to us as members of an entirely different cell, with a large, clear nucleus and ample cytosome. In the egg the contrast between stages is even more remarkable, but here also the nucleus grows with the cytoplasm.

From these observations we must conclude that if the nucleus governs metabolism, and many observations tell us this is true, the unusual condition of the nucleus is the cause for the unusual growth of the cytosome. The possibilities for the new growth are established by the unified activities of the chromosomes from the two parents, I would conclude. But the cytoplasmic growth is only one aspect of the change that has been taking place at this time. The chromosomes themselves have been active participants in a series of interactions that leave them modified in structure and function in many cases, the only exception being such as govern Mendelian characters. Undoubtedly the nature and amount of this interaction vary between the same chromosomes in different generations, and herein is the cause of variation. Once the chromosomes are separated in maturation, however, their character is determined and they do not again alter in the germ-cycle until another synapsis. I believe these views are established by common observation. The descendants of two parents rarely develop body characters much alike, but now and then real twins appear and they are strikingly alike. The reasons for this are not far to seek, for the twins are the product of the same two germ-cells, while ordinary children are from different cells in each parent.

From the plant kingdom we may gain still further evidence

of the same nature. Here, where vegetative reproduction may be carried on for long periods of time, there are forms that suffer practically no variation at all under these conditions; but allow them to propagate sexually and variation occurs as usual. In a self-fertilized plant the material comes from one source in both cases, but in vegetative propagation the same double set of chromosomes reproduces itself constantly unchanged; but in sexual reproduction there is the interaction of chromosomes in synapsis and the formation of a new cytoplasm that is lacking otherwise. The fundamental importance of the germ-cell organization is thus indisputably proved.

With the chromosomes in the role of character determinants, how then may we regard the operation of the cell parts? We must, in the first place, I think, consider the cyclical character of cell division. Nucleus and cytosome are physically and chemically unlike structures, separated by a thin membrane. There can be no doubt that the ordinary phenomena of osmosis find a place with consequent interchange of materials. After a cell division the cytosome grows, the nucleus grows, and the chromatin doubles its volume. New material has been added and transformed into the likeness of the old. Experiments teach us that the presence of the nucleus is required for the operation of these changes. Then comes another mitosis. The nucleus as a discrete body disappears and its protoplasm merges with that of the cytosome. Thereupon there is formed the familiar bipolar figure and the chromosomes are accurately divided along a plane established before the breaking down of the nucleus. This occurs in the spermatogonia, where the cytoplasm is reduced in amount to such a degree that so minute a spindle is produced that it can scarcely be distinguished among the chromosomes. The division of the chromosomes is the final effort of these cells. That such a process would produce equivalent daughter-cells seems obvious. A similar occurrence obtains in the reproduction of somatic cells, but there is an important difference between the two categories. In the division of the spermatogonia there is a constant increase of the chromatin at the expense of the cytoplasm, resulting in cells a very large proportion of which individually is chromatin, while in somatic mitoses the cytoplasm enlarges disproportionately to the nucleus and its chromatin. This cytomorphosis seems to exhaust the possibilities of differential interchange between nucleus and cytosome, and fixes the character of the cell.

In the fertilized egg the conditions are much different. Preceding the entrance of the spermatozoon the synaptic chromosomes have operated in the process of building up both a large nucleus and a large cytosome. At maturation most of the nonchromatic material is discharged into the cytosome, so that upon their conjugation the pronuclei are probably equivalent in other respects aside from the chromosomes. It has been shown that in the early stages of embryo formation there is an actual contribution of chromosomic material to the cytoplasm. That the chromosomes increase in size after each division by taking up material from the cytoplasm is a common observation. There is thus a constant circulation of material through nucleus and cytosome, and that, I consider, offers an adequate explanation of the *means* of differentiation, for if the chromosomes were individually different they would respond adaptively under the varying conditions of development.

Assuming this as an explanation of the means of differentiation, how can we conceive the operation of the processes of development in relation to the germ-cells, which divide at the same time as the body-cells and yet suffer no differentiation? The only observations that would serve as a key to this problem would indicate that the absence of differentiation is due to the retention of the entire chromosome complex unchanged. If differentiation is due to the interchange of material between the chromosomes and cytoplasm under like conditions, it would naturally follow that the absence of differentiation might result were there no such interchange. The few observations that we have would support this view. We are, however, much in need of a thorough knowledge of the changes undergone by all the cell elements during ontogenetic development. We would have a much broader foundation for our theories if we knew the nature of the chromosome complex in the various cells of the body as these became differentiated. It would then be possible to say, with more assurance than our present scanty observations incline us to do, that the germ-cells preserve the chromosome complex unaltered, while it becomes progressively and variously changed during histogenesis.

It is very clear that we cannot look to any variation in the operation of mitosis as a cause for somatic differentiation, since our observations indicate that the process is designed to produce exact chromosome equivalents. If the chromosomes are the controlling centers of differentiation, then the only con-

ception of their action that we can entertain is that they bear definite and progressively different relations to their cytoplasmic environment. Differentiation, we should therefore be inclined to say, is due to a series of adjustments between two constantly varying and interdependent structures, nucleus and cytosome, with the chromosomes acting as the measure of their interaction.

There has been in reality but one thing postulated as a basis for my views regarding the organization of the chromosomes, viz., that they are specific, self-perpetuating morphological units. If this be granted, synapsis, segregation and double chromosome groups necessarily are true conceptions, for there is no other way of accounting for the reduction in the number of chromosomes in mauration and the restoration of this number in fertilization. Once it is conceded that the chromosomes are self-perpetuating cell units, then there can be no questioning the fact of a reducing or segregating division, for if a set of chromosomes from the father enters the egg and duplicates a set already present no other explanation of the reappearance of the same two sets in the mature germ-cells can be offered. The whole question of heredity based upon chromosome structure centers here. Every fact that makes for the establishment of the chromosomes as definite structural elements is an argument in favor of a reducing or segregating division. *The loss of the identity of the chromosomes in any period of cell proliferation means the recreation of the chromosomes in the next mitosis.* This fact must be clearly realized. If they are not continuous structures they are new structures in each cell. If they are *new* structures, then it must be explained how they reappear in the same number, size and form from generation to generation of cells and throughout the species, genus and family of the grasshoppers. To say that they form anew after each mitosis is to postulate an organization outside of themselves that controls their reintegration. This merely begs the question, for we know of no such organization. I maintain that the discovery of the same group of chromosomes in all the species of *Hesperotettix* is alone sufficient to establish the fact that they are self-perpetuating individuals. We actually see them reproducing themselves in one mitosis after another, and we find them invariably in every animal that we study.

Now, in arguing thus for the continuity of the chromosomes, it is not intended to convey the idea that they are always of

exactly the same size, form and physical constitution, nor that there is not addition to, or change in, the material substance of which they are composed. They are no more immutable or invariable than the grasshopper which at one time is an egg, at another a nymph, and finally a full-winged adult. I would as soon question the individuality of one as of the other, on the argument that they cannot always be distinguished in the same form. Enough evidence has now been developed by various cytological and experimental researches to show that there is a fixity and definiteness in chromosome organization sufficient to support adequately what is commonly known as the theory of the "individuality of the chromosomes." The burden of proof rests strongly upon those who oppose this theory, and to remove it they will have to offer some definite explanation for the appearance of such a structure as the hexad multiple of *Hesperotettix*.

The mere fact that the chromatin granules diffuse through the nucleus so that the outlines of the individual chromosomes cannot be distinguished is no argument against the persistence of the chromosomes. Neither can I regard the occurrence of occasional cases of amitosis as in the least weakening the theory of chromosome individuality. It may teach us more about chromosomes to learn that under some circumstances they may show such a suspension of visible integration as amitosis would indicate, but we shall first have to know a great deal more about amitosis than we do now, and we shall want to know how much the parasitical nature of the forms in which direct division usually occurs has had to do with the modification of all other organic phenomena. In other words, I maintain that other than negative evidence will have to be offered in explanation of the occurrence of the same number of chromosomes throughout the family *Acrididæ,* and of the same combination that characterizes certain genera. If these are not self-perpetuating structures then there is some agent outside which determines their being, and it will be necessary to demonstrate this before the simpler self-integration theory is abandoned.

I am quite prepared to admit also that in one species even there may be a variation in the integration of the chromatin material, resulting in some numerical variation of the chromosomes, without losing my belief in the necessity for this defi-

niteness in the grasshoppers. We do not yet know how much difference there may be in the organization of the various chromosomes of a complex nor how variable in importance they may be. We know that eggs differ much in the extent of their organization, so that their potencies are entirely different; and since the chromosomes represent a part of this organization they also may vary in some forms. There may also be more than the duplicate set of chromosomes present, which would presumably do no more than bring about greater variation or minor differences in the distribution of characters.

Taxonomy has sought to determine the true relationship between animals and to divine the lines of their descent. As criteria they have used, in the main, structural peculiarities, and these have been considered of different values, depending upon the number and variety of forms to which they are common. We speak in this way of family, generic and specific characters. For instance, in the Orthoptera we distinguish the family *Acrididæ,* which has as recognition characters strongly developed jumping legs, vertical head, short antennæ, three ocelli, three-jointed tarsi, auditory organs on the basal segment of the abdomen, etc. An examination of these characters will show that it is not the presence of any peculiar structure that distinguishes this group of Orthoptera from other Orthoptera, but it is the nature and extent of structural development that is distinctive. All insects have, for instance, a third pair of legs, a pair of antennæ, a head, etc., but in the *Acrididæ* it is the particular proportion of the third pair of legs, the length of the antennæ, and the position of the head with reference to the thorax that marks off this group from others. It is the entire organization of the acridian body that differs from representatives of other orthopteran families, and these features of external structure that taxonomists have selected are merely very striking ones used for diagnostic purposes.

Not a cell in the body of an acridian is like that of a locustid, nor are any of the organs similar. The structure of the testis, for instance, is so dissimilar that a glance at a section through a low power of the microscope is sufficient to distinguish the source of the preparation without counting the chromosomes. I have therefore come to the conclusion that for accurate, systematic work, not only will the external anatomy have to be studied but also the internal. Ordinarily, the correlation of

parts is sufficiently close to allow the use of purely external structures, but in other instances the entire anatomy will have to be understood. It has been a matter of great interest to me to find how real are the distinctions between species that have been established by systematists. In the genus *Hesperotettix*, that I have been using as an example, the species are clearly marked by peculiarities of external structure, color, etc., and these are strictly correlated with germ-cell characters.

These things all speak strongly to me of definiteness and thoroughness of organization, a conception that we ordinarily express as "correlation of characters." It means, in truth, that an organism is a very complex assemblage of parts, each of which at any particular time has a definite form and relation to the other parts. To know it thoroughly we must be familiar with *all* its parts at that particular stage which it has reached in its development. An organism is an organism, no matter at what ontogenetic period it is regarded. Practically all crustaceans, as we know, at one stage of their existence have a form called a "nauplius." The definitive organization may express itself by only slight modifications of the early type of structure, or it may progressively alter its form until it bears no resemblance to the former condition. But these nauplii are not all alike, and doubtless every form has a different expression for this structural type could we but distinguish it. Not only is this true, but in all probability every cell is characteristically different.

With this conception of organisms we see that in their study the distinction between cytology and taxonomy is not great. Were our knowledge of cell structure in the grasshopper complete enough we might erect a system of classification based upon cytological characters, just as reasonably as we have designated one using external anatomical structures. All of which goes to show that organisms at all stages of development and in all their parts are specifically constituted. It is the peculiar privilege of cytology not only to recognize these differences but to determine the means by which they came about. The apprehension of large principles of organization should therefore be our aim, and I have no doubt that once an understanding of the cytological changes in the body of an animal during its ontogeny is reached we shall have solved, as far as it is possible for us to do, some of the larger problems of heredity and development that have become our scientific inheritance.

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BIBLIOGRAPHY, WITH BRIEF HISTORY, OF THE DEPARTMENT OF ZOOLOGY, UNIVERSITY OF KANSAS.

BY C. E. McCLUNG.

(Contribution from the Zoölogical Laboratory, No. 175.)

THE history of a department in an educational institution may be likened in many ways to the history of a race of organisms. It is usually a more or less generalized organization in the beginning, and only after a time reaches the precision and specialization that is characteristic of a well-planned and directed department. Like organic groups, also, it may undergo a degree of specialization that the environment will not support, and, like them, be obliged to suffer in consequence. The department of zoölogy at the University of Kansas is no exception to this rule, and its history is a record of successive adaptations to circumstances with consequent diversity and specialization.

In an endeavor to catalogue and arrange the publications of the department the writer has been obliged to investigate the various stages in the development of this part of the University, and, as a result, has come to the conclusion that it would be both desirable and proper to put on record the facts thus discovered. It is especially appropriate that this be done, since the man who is responsible for the founding of the department has played so large a part in the life of the school from its very beginning up to the present time, and has thereby impressed a strongly scientific cast upon it. Doctor Snow, by his devotion to biology, has succeeded in placing the University of Kansas well up in the ranks of scientific schools, especially on the museum side. It is due him, therefore, that his connection with the department be recorded in detail.*

* It is a matter of great regret to the writer that this slight public appreciation of Doctor Snow should not have appeared during his lifetime; but even as the printer's proof was undergoing revision there came the news of his death, September 20, 1908.

The University catalogue of the year 1866, in the faculty list, shows the name of Frank H. Snow with the title of Professor of Mathematics and Natural Science, but in the following year mathematics does not appear as a part of his official designation. The first step in specialization was thus early taken. No further advance was made, however, until 1899, when biology was made his main work, as appears from the title, Professor of Botany, Entomology, and Meteorology. The professorship in zoölogy at this time descended to Lewis Lindsay Dyche, whose connection with the department of natural history began during his junior college year, when he is recorded, in the catalogue of 1882, as Instructor in Natural History. In 1886 he became Assistant in Natural History, in 1888 Professor of Anatomy and Physiology, and in 1899 Professor of Zoölogy.

During the twenty-four years of his incumbency as Professor of Natural History Doctor Snow gave all the instruction in the general subjects of botany, zoölogy, and geology, and in the special branches of meteorology and entomology. Emphasis was laid upon individual work by the student, and in the catalogue of 1878 it is stated ". . . the chief end to be accomplished is the cultivation of the faculties of observation and comparison." From the beginning, however, his strong interest lay in the development of a museum, and as early as the year 1869 there appears in the catalogue an acknowledgment of the gift of 600 plants, 500 insects, and 50 fish and reptiles by Frank H. Snow. In subsequent catalogues there are always records of the numbers of specimens in the museum. Beginning in 1875 with 30,000, the increase is steady, with an addition of about 10,000 annually, until 100,000 is reached in 1882. The 150,000 mark was passed in 1887, and this remains as the record at the end of Doctor Snow's active teaching period, when he became Chancellor of the University in 1890.

Upon the division of the work in the department of natural history in 1889, Doctor Snow had associated with him W. C. Stevens as Assistant in Natural History and V. L. Kellogg as nated as Director of the Museum, and this title appears after Assistant in Entomology. At this time he was officially desig- his name until the catalogue of 1895. The same personnel was maintained in the department until 1894, when W. A. Snow, the elder son of Doctor Snow, took the place of V. L. Kellogg, and Hugo Kahl became Museum Assistant in Entomology. In

1896 S. J. Hunter took up the work of W. A. Snow. A separation of the department of botany under the charge of W. C. Stevens was effected in 1898, when Doctor Snow's title became Professor of Organic Evolution and Entomology. As such it remained until the catalogue of 1901 records it again in the old familiar form of Professor of Natural History and Director of the Museum. In the following year it was again changed, to read Professor of Organic Evolution, Systematic Entomology, and Meteorology, in which form it remains at the present time. After relinquishing the chancellorship Doctor Snow resumed active teaching in the subject of organic evolution, and took up again his favorite work of field collecting in entomology. He has in this time added many thousand specimens to the museum. As a result of his efforts the University of Kansas now possesses one of the three largest collections of insects in this country. If this were the only outcome of his long connection with the University it would be a worthy achievement.

From the original department of natural history there was separated off in 1889 the independent department of geology and paleontology, under the charge of S. W. Williston. This remained unchanged until 1892, when physical geology was made a separate department, with E. Haworth at its head. Doctor Williston's official designation then became Professor of Historical Geology, Vertebrate Anatomy and Physiology, in which form it continued until 1898. At this time a separate department of physiology was created, with Ida H. Hyde in charge, and Doctor Williston's title was changed to Professor of Historical Geology and Vertebrate Anatomy, and Dean of the Medical School, in which form it remained during his connection with the University. Upon his departure in 1902, G. H. Hoxie took up the work in human anatomy and C. E. McClung became Acting Dean of the Medical School. The anatomy work came under the direction of M. T. Sudler in 1905, when he also became Dean of the Scientific Department of the Medical School, and is still in charge.

The history of the zoölogy department proper runs a very uniform course from the time of its formation as a separate department in 1888 until the present time. Professor Dyche had the title of Professor of Anatomy and Physiology, Taxidermist, and Curator of Birds and Mammals, in 1888, and retained it until 1892, when it was shortened to Professor of Zoölogy and Taxidermy. In the following year it was modi-

fied slightly, reading then Professor of Systematic Zoölogy and Taxidermy, and in this form continued afterward unchanged. Gertrude A. Crotty was made assistant in the department in 1889, and remained until 1892. No successor was appointed to her position until 1896, when R. C. Gowell took up the work. His untimely death in the following year again left the place open. The vacancy thus occasioned was filled in the spring term of the year 1897-'98 by the appointment of C. E. McClung, then student assistant in the department of paleontology, as Assistant Professor of Zoölogy. This title was changed in 1900 to Assistant Professor of Histology and Animal Morphology, in 1901 to Associate Professor of Zoölogy, and in 1905 to Professor of Zoölogy. Doctor McClung became head of the department in 1901, and has continued in that capacity since.

The position of Instructor in Zoölogy was established in 1900, and its first incumbent was Walter S. Sutton, who was succeeded in the following year by Maulsby W. Blackman. No further change was made in this place until 1904, when William J. Baumgartner followed Mr. Blackman. In 1905 Mr. Baumgartner became Assistant Professor of Zoölogy, and Miss Mary Augusta Duke was made Assistant Instructor in Zoölogy. Miss Nadine Nowlin took the place of Miss Duke in 1906, and Richard E. Scammon was added to the faculty as Assistant Instructor. A fellowship in biology was founded in 1905 and Roy G. Hoskins was its first holder. It is now entitled a fellowship in zoölogy and its incumbent is Earl Clark.

Upon the departure of Doctor Williston in 1902 the work in vertebrate paleontology reverted to the department of zoölogy, and the title of Curator of Vertebrate Paleontology was transferred to Doctor McClung. Associated with this work as preparator was H. T. Martin. In 1906 he became Assistant Curator of Vertebrate Paleontology and so continues. Previous to the appointment of Mr. Martin as preparator, Judge E. P. West, T. H. Overton, and E. S. Riggs were employed in this capacity. Judge West made extensive collections and inaugurated the work of systematic preparation of specimens. For several years Sidney Prentice was artist in the department.

At various times there have been men connected with the department, some of whom were more or less associated with instruction work, while others had no direct relation to it. Because no mention is made in the earlier catalogues of such

helpers in the museums and laboratories it is impossible to give a complete list, but the following are known to have been associated with the affairs of the department: Messrs. Eames and Wyland were for a number of years employed as taxidermists, and it was during their connection with the museum that the major part of the collections now on exhibition were mounted. Succeeding these men in 1895 was C. D. Bunker, who is yet a member of the department, with the title of Assistant Curator of Birds and Mammals. In 1902 L. A. Adams was made Museum Assistant in Zoölogy, and continued in that position until 1905. While existing as a separate department of paleontology there were employed a number of men, generally graduate students, who devoted some of their time to preparation work. Among these may be mentioned E. C. Case, Alban Stewart, E. S. Riggs, W. N. Logan, and E. H. Sellards.

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ICHTHYOLOGICAL NOTES OF THE KANSAS CRETACEOUS, I.

BY C. E. McCLUNG.

(Contribution from the Zoölogical Laboratory, No. 176.)

Plates X to XIII, and ten figures.

DURING the course of a restoration of the extinct Cretaceous fish, *Xiphactinus* Leidy, a number of points concerning its anatomy came up for consideration. Several of these called for considerable study, and it was found that they had not been completely worked out before in any specimen. In particular, these concerned the pectoral girdle, the opercular apparatus, and the mandible. It is my purpose in this paper to present, among other things, the facts that appeared from this study.

OPERCULAR BONES OF XIPHACTINUS.

Of this series the operculum, preoperculum, and suboperculum have received extended descriptions at the hands of Stewart, but the exact identity of the suboperculum was not determined, since it is indicated as the "supposed suboperculum." The interoperculum is figured under the caption of "bones of uncertain position." While this entire series has not been observed in position, I feel confident that the relations indicated in figure 1 cannot be far wrong. From the inner side it can be seen that the interoperculum upon this surface has a facet that articulates with a corresponding one on the suboperculum, and when these are in contact and the bones in position the opposite, roughened extremity of the interoperculum just comes into contact with the rugose angular of the mandible. I am therefore of the opinion that the location of the members of this series has been determined with some degree of certainty. Unfortunately the interoperculum is very thin and fragile on

its ventral edge and this is always broken. The complete form cannot therefore be determined from the material now on hand. The most complete specimen in this museum is shown in figure 2. This is the same specimen figured by Stewart ('00, plate 44, figure 5). It is therefore apparent that the opercular apparatus of *Xiphactinus* is of the typical teleost form and presents no peculiarities of importance.

MANDIBLE.

Cope, Crook, Hay and Stewart have described the mandible of *Xiphactinus*, and the main points of its structure have been well presented. The only questions that have arisen concern the articulars and the angular. From the material at my command I am able to state with considerable certainty the form and extent of these elements. An angular is present and is united suturally with the dermaticular principally, but is slightly in contact also with the autarticular and the dentary. Not infrequently, however, it has become separated entirely from its contacts, and in that event its limits are clearly indicated by the strongly roughened sutural surfaces of the remaining bones. In figure 3 is shown a mandible with the angular lacking. It is therefore seen that this element is a small, irregularly triangular structure, and not large, as Cope described it. Hay figured it ('98, p. 36) as a part of the dermarticular, Cope ('75, p. 195) as a portion of the articular (= dermarticular).

With the removal of the angular the nature and extent of the dermarticular is at once apparent, and it may be traced forward into the long process attached to the inner side of the dentary. This portion of the bone is regarded as belonging to the angular by Cope ('75, p. 195) and to the autarticular by Hay ('98, p. 37). There can be no question regarding the identification of this element in the specimen before me. The dermarticular is therefore a large bone, extending fully two-thirds the length of the mandible, and from the ventral edge to the coronoid process. The "sword-shaped process" is merely a thickening of the bone on its ventral edge, and above this it suddenly thins out very much. Into the groove thus formed there rests the autarticular, a short, wedge-shaped bone of irregular outline, whose broad base affords the main articulating surface of the mandible with the quadrate. In front of the autarticular, and resting in the same groove on the inner surface of the dermarticular, is a small, triangular-shaped bone

which Stewart ('00, p. 273) refers to as the "supposed splenial." This is a separate element and can be nothing but the splenial. The two main divisions of the mandible are thus seen to be the dentary and the dermarticular. The latter element forms what might be regarded as the axis of the ramus, with the dentary attached to the outer surface and the autarticular, splenial and angular to the inner. The relative positions of these bones, as seen in a caudal view, are represented in figure 4.

PECTORAL GIRDLE OF XIPHACTINUS.

The pectoral girdle has received considerable attention and, while at first much misunderstood, is now well known in its general features. Some exceptionally good material, however, makes it possible for me to add to our knowledge of this portion of the anatomy and to dispose of a few more unknown or problematical bones. Hay ('98, fig. 9) and Stewart ('99, pl. 45A, figs. 1, 2) have represented major portions of the girdle. In each instance, though, certain elements are omitted, and the relation of the right and left halves is not shown. I think it possible from the specimen before me to present a fairly complete picture of the entire girdle.

In figure 5 is shown a cephalic view of the two girdles in position, with the horizontally directed portion of the clavicle crushed and broken. Very probably this specimen shows the normal relations of the two halves. The hyper- and intercoracoids of the two sides are here seen to be in contact throughout their dorsoventral extent, but an inspection of separated arches indicates that intimate union was restricted to the hypocoracoids. Rising from the dorsal edges of the intercoracoids are the mesocoracoids, which define the space between the two arches. External to the heavy rod-shaped mesocoracoids, and separated from them ventrally by an irregular oval foramen, are the dorsal wings of the clavicles. These are thickened along their cephalic edges where they are in contact with the mesocoracoids, but caudally and beyond this they are thin and delicate. In most specimens this part is broken and gone.

The relations of these parts as viewed from the caudal side may be seen in plate X, drawn from the same specimen after removal from the matrix. The separation of the mesocoracoid and clavicle, except at the cephalic edge, is very evident. Here may also be observed the somewhat complicated sutures be-

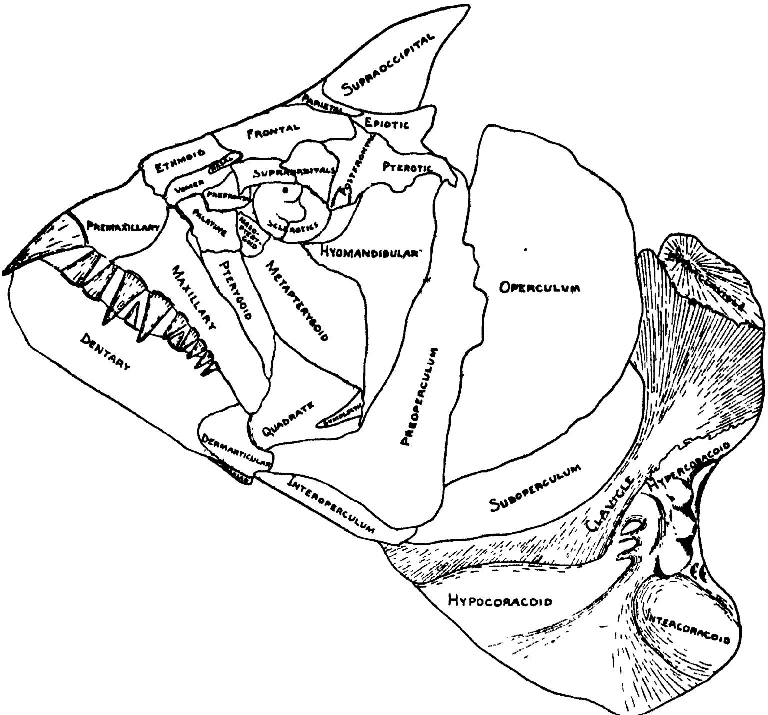

FIG. 1. Restoration of the skull, opercular apparatus, and pectoral girdle of *Xiphactinus*.

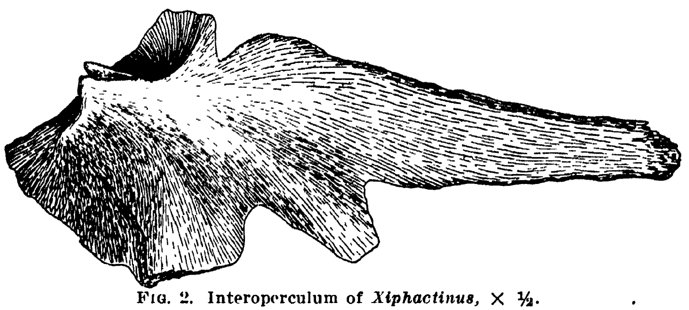

FIG. 2. Interoperculum of *Xiphactinus*, × ½.

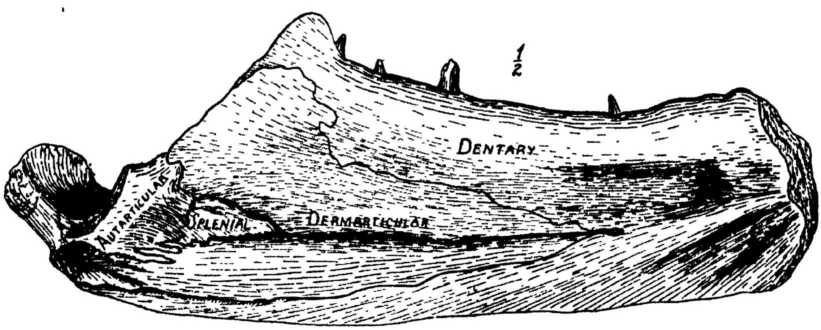

FIG. 3. Internal view of left mandible of *Xiphactinus*, *ca.* × ½.

tween the elements of the girdle. The hypercoracoid is expanded into a broad, thin plate as it disappears under the clavicle. It extends to the ventrocaudal border of the clavicle and dorsally to over half its height. This forms the outer boundary of a long dorsoventral fissure, the entire inner limit of which is fixed by the mesocoracoid. Only above the hypercoracoid plate does the clavicle border this cleft. Hay ('98, p. 43) was in error when he described this fissure as being limited by the outer and inner plates of the clavicle. In the very slightly crushed specimen from which plate X was made the relations of the coracoid elements are beautifully shown. The sutures joining these lie immediately back of the articular facets. Between the hyper- and hypocoracoid is a bone that has not heretofore received notice, and I am unable to homologize it with any described element of the girdle. I shall therefore, because of its position, call it the intercoracoid. It is small and wedge-shaped, with the apex directed dorsally against the base of the mesocoracoid and a mesial wing extending ventrally to unite with the hypocoracoid. Its separation from the hypercoracoid is strongly marked by a heavy suture passing through the fossa where the second baseost is set. A heavy, rounded process arises from the outer dorsal edge of the hypocoracoid and impinges against the ventral, horizontally placed surface of the intercoracoid, just in front of the facet for the articulation of the fin-rays. Some of these relations are better seen in a lateral view, and will be referred to later.

The mesocoracoid rests broadly upon the intercoracoid, and is joined to it by a heavy suture that runs almost horizontally. Above the oval foramen the mesocoracoid sends a broad wing that joins the inner surface of the hypercoracoid at about the level of the outer suture between this bone and the clavicle. The articular facets of the hypercoracoid form an almost straight line, whose angle on inclination is about forty-five degrees from the median plane of the animal. Upon the caudal margin of the hyper- and intercoracoids, at the level of the interspace between the middle and lower facets, are two fossæ for the reception of the T-shaped baseosts. The outer of these lies equally upon the two bones, but the inner and shallower one is entirely confined to the intercoracoid, although its dorsal margin touches the suture uniting this bone to the mesocoracoid.

An external view of the girdle shows all the elements more

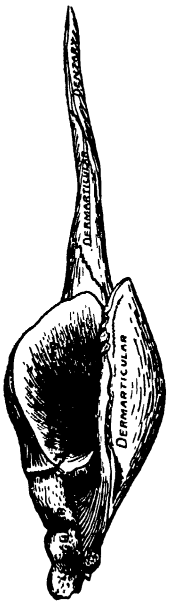

FIG. 4. Caudal view of the right mandible of *Xiphactinus*, × ½.

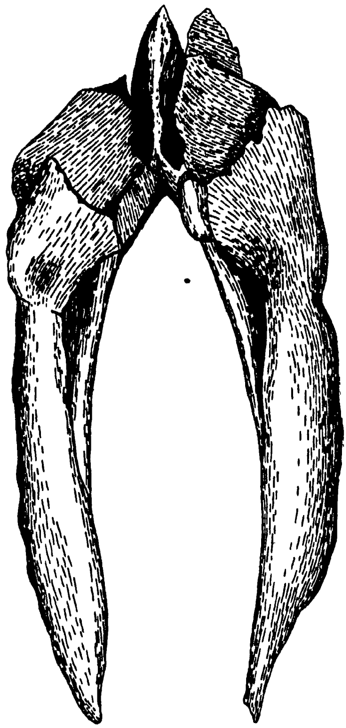

FIG. 5. Cephalic view of the pectoral girdle of *Xiphactinus*, × ¼.

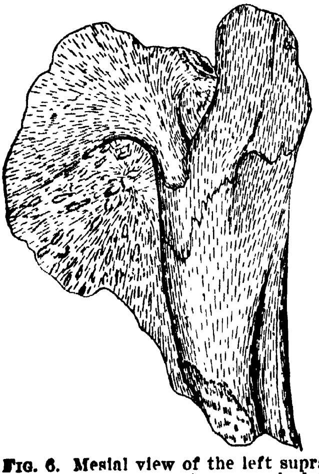

FIG. 6. Mesial view of the left supraclavicle of *Xiphactinus* attached to the clavicle, which is interposed between it and the mesocoracoid, × ⅛.

FIG. 7. Proximal ends of fin-rays of *Xiphactinus*, showing their articulations with the girdle and baseosts, × ½.

or less completely. The largest of these is the clavicle, which only slightly exceeds in size the hypocoracoid. Between these elements is placed the heavy hyper- and intercoracoids, the former bearing the facets for articulation with the fin-rays. The dorsal portion of the hypercoracoid is joined by a heavy suture to the ventral border of the vertical limb of the clavicle. Beyond this point, as was noticed in the description of the caudal view, a thin plate extends dorsally between the clavicle and mesocoracoid. The inner ventral margin, at the level of the lower and middle facets, is joined to the inter- and mesocoracoids.

Except for a heavy process arising from the outer surface to join the ventral edge of the intercoracoid, the hypocoracoid is a thin, fragile bone which is nearly always broken at the edges. From a number of specimens the various parts of this edge have been observed and from them the restoration in plate XI made. Just in front of the suture joining this bone to the hypercoracoids is an oval foramen piercing the hypocoracoid. This was described as absent by Hay ('98, p. 43). Sometimes there are several of these. Ventral to this are two stout processes running forward, approximately parallel. These join the stout dorsocaudal process of the hypocoracoid to its thin inner plate. Elsewhere these are separate. Aside from these diversities the bone is uniformly thin, except at the dorsal edge, where it thickens strongly to join the hyper- and mesocoracoids.

The clavicle has been well figured and described except that usually it has been represented as too narrow dorsally. But so far as I have been able to discover there has been no record of the supraclavicle that attaches to the dorsal edge of the clavicle. This is the "uncertain bone" shown by Stewart (figure 2, plate 44). A portion of it is attached to the girdle from which Stewart's figure 1, plate 45A, was made, but it does not appear in the drawing. In a number of specimens it can be seen, on the inner side, attaching firmly to the caudal margin of the dorsally projecting process of the clavicle, and, by means of a thickened ridge, to the angle which this clavicular process makes in descending to join the dorsal edge of the mesocoracoid. Upon the inner surface of the thin, caudal portion of the clavicle it becomes much attenuated and gradually thins out. It does not anywhere come into relation with the mesocoracoid. (See figures 1 and 6.)

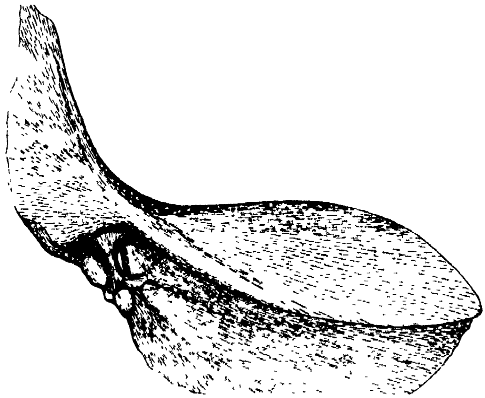

FIG. 8. External view of the right side of the pectoral girdle of *Gillicus*, × ½.

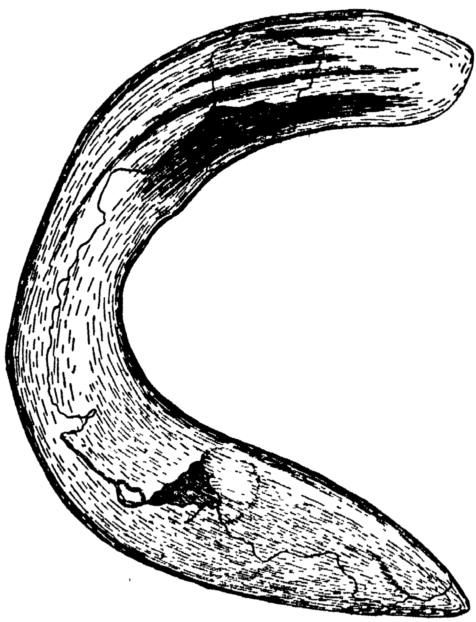

FIG. 9. External view of right half of the pectoral girdle of *Protosphyræna*, × ⅛.

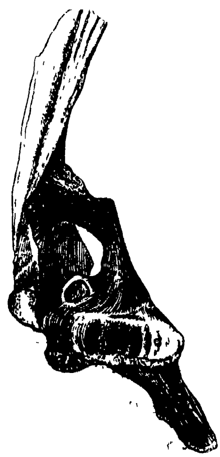

FIG. 10. Caudal view of left half of pectoral girdle of *Protosphyræna*, × ½.

The articulation of the fin-rays with the girdle has been correctly described, in its general features, by Stewart ('00, p. 284), but a few details may be added. In figure 7 are shown the proximal ends of the fin-rays, and upon them, in dotted outline, the largest baseost. The fainter dotted outlines within represent the articular facets which are applied to the lower two of the hypercoracoid. The deep depression in the proximal end of the first dorsal fin-ray abuts against the upper facet of the hypercoracoid. Upon the opposite side of the large baseost are a number of articular surfaces for contact with the ventral fin-rays. Just under the proximal ventral facet (*a* of figure 7) is a large flattened surface which articulates with a similar area upon the proximal end of the first ventral fin-ray. At the opposite extremity is an elongate, irregular facet which affords contact with the second, third, and possibly fourth, ventral rays through their facets *c*, *d* and *e*. The exact position in the fin apparatus of the two T-shaped baseosts is not exactly determinable, but their proximal ends are set in the two deep depressions of the hypercoracoid and intercoracoid. The distal ends, with their broad articular surfaces, undoubtedly bore upon the proximal ends of the fin-rays.

The relative positions of the various bones may be seen from an inspection of plate XII, which is from a photograph of the restoration in the University of Kansas.

PECTORAL GIRDLE OF GILLICUS.

Several fine specimens in the museum of the University of Kansas make it possible to give a fairly complete picture of the pectoral girdle of *Gillicus*. One is at once struck with the general resemblance this bears to the corresponding structure in *Xiphactinus*. Such differences as there are may be referred very largely to variations in proportions. An examination of figure 8 will give a general idea of the lateral aspect of the girdle. Here it will be seen that the ventral limb of the clavicle is much larger in proportion than it is in *Xiphactinus*. The dorsal limb is of the same general form, but no supraclavicle was found. In all probability it was present, however, for an articular surface similar to that of *Xiphactinus* is evident. The hypocoracoid also is larger in proportion and is widely separated from the large ventral limb of the clavicle, except at the dorsal edge, where they are in contact.

The hypercoracoid is a miniature replica of the corresponding bone in *Xiphactinus*. The facets for the articulation of the

fin-rays and baseosts are similar in form and position. The two cup-shaped depressions for the reception of the T-shaped baseosts are present and the first is bisected by the suture separating the hypercoracoid from the intercoracoid. The mesocoracoid, like all the other bones of the girdle, is not so robust as the corresponding element of *Xiphactinus,* but in form and position is similar to that of the larger fish. Indeed, the very evident and minute resemblances between the pectoral fin apparatus of *Gillicus* and *Xiphactinus* clearly point to the close relationship between the genera and justifies their inclusion in a common group.

GIRDLE OF PROTOSPHYRÆNA.

The girdle of this genus has been described at considerable length by Cope and Hay, and the specimens at my command enable me to add only some small details to what has already been published. In figure 9 is shown an external view of the clavicle, from which it is evident that only a part of the bone has previously been figured. Hay shows in his figure 7, page 13, the most complete specimen that I have seen mentioned. Cope represents only fragments attached to the heavier bones. On the dorsal limb the cephalic edge is much thickened (figure 10), strengthening the girdle after the manner of the mesocoracoid in *Xiphactinus.* The specimen from which figure 9 was made is not well preserved, having been taken from the shaly lower stratum of the chalk, but the outline of the entire bone was preserved in the matrix and is shown in the restoration.

The relations of the complex of girdle bones is shown in figure 10, drawn from a specimen that has suffered very little distortion. Unfortunately, the sutures are almost entirely obliterated by the close union of the various bones, so that little can be added to what is already known regarding the limits of the individual elements. Owing to the undistorted condition of the specimen, however, the exact form and position of the various parts are clearly shown. Thus the mesocoracoid is observed to occupy somewhat the same position that it does in *Xiphactinus,* leaving an oval foramen between itself and the upward extension of the hypercoracoid. Instead of being suturally connected with the clavicle it rests in a depression formed by the straight, ventral extension—past the curved cephalic edge—of the thickened process of the clavicle. The hypercoracoid is not suturally separated from the hypercora-

coid but is a heavy bone bearing three facets for the articulation of the fin-rays. Very probably also it contains one or more of the six oval pits for the reception of the baseosts, since the mesocoracoid rises above the first, second and third of these. The fin-ray articulations are quite unlike those of *Xiphactinus* and *Gillicus*, being much roughened for the attachment of ligaments. The entire construction of the girdle would indicate little movement of the fin, which was apparently more or less rigidly braced against the body. The hypocoracoid is a heavy, irregular bone, large dorsally, where it bears some of the pits for the baseosts, and thinner ventrally. It is flattened in a cephalocaudal direction at right angles to the plane of compression in the clavicle. In the specimen from which figure 10 was drawn the ventral portion shows a roughened edge, probably indicating the presence of another element.

It is evident from the construction of the girdle that the differences are considerable between *Protosphyræna* and the other genera considered here, and lend further justification to the classification which places it in a group by itself.

CAUDAL FIN OF PROTOSPHYRÆNA.

The entire skeleton of any member of this genus has not yet been discovered. There is therefore lacking a knowledge of several portions of the body, among which are the occipital region of the skull, the vertebral column and the caudal fin. Light upon all these points is afforded by material now at my disposal. I wish here to consider the caudal fin and incidentally the vertebræ. Through purchase from Mr. C. H. Sternberg the University of Kansas has come into possession of a specimen of the caudal fin, which not only shows the nature of this organ but also clearly demonstrates the absence of ossified vertebræ. In plate XIII is represented a lateral view of this specimen, from which the essential features may be understood without much description. The ossified neurals and hæmals appear very plainly, as they do in the nearly related *Hyposocormus*, according to Woodward, but the centra are absent. The last hæmal is considerably modified, forming a urostyle, to which many of the fin-rays attach. This bone is frequently found by collectors, but its character and relationships have not heretofore been understood. The fin-rays are fine, closely apposed and very numerous. In the specimen under consideration they are incomplete and broken, so that the exact form of

the fin cannot be ascertained. Apparently it was broad and firm.

Owing to the isolated condition of the specimen its specific position cannot be determined, and any attempt to do this would be only a guess. It is an important specimen, however, since it definitely places the genus in the family *Pachycormidæ*, upon the assumption that only the uncertainty of vertebral characters previously made the classification doubtful.

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RESTORATION OF THE SKELETON OF BISON OCCIDENTALIS.

BY C. E. McCLUNG.

(Contribution from the Zoölogical Laboratory, No. 177.)

Plate XIV.

ONE of the most interesting and striking specimens in the paleontological museum has just been placed in its case. This is a specimen of the extinct *Bison occidentalis*, collected and mounted by Mr. H. T. Martin. This, I believe, is the first time that a complete skeleton of one of our ancient bisons has been assembled, and the technical excellence with which the mounting has been done by Mr. Martin is worthy of this distinction. The skull of this specimen has been described by Mr. Alban Stewart under the name of *Bison antiquus* (Kansas University Quarterly, vol. 6, No. 3), and by Mr. F. A. Lucas (Proceedings of the United States National Museum, vol. 21, 1899) as *Bison occidentalis*. For this reason a detailed description of the cranium is hardly necessary. For the sake of completeness a statement of the circumstances connected with the discovery of the specimen will be given, although this has also been reported by Dr. S. W. Williston.

Particular importance attaches to the finding of this specimen, for during its removal an Indian arrow-head was discovered beneath the right scapula. I give Mr. Martin's own account of its history herewith:

"In the summer of 1895 Mr. T. R. Overton and I were collecting in the vicinity of Russell Springs, Logan county, Kansas, when our attention was called to some mammalian teeth found by Mr. Charles Wood. An examination of the teeth disclosed the fact that they belonged to an extinct form of bison.

Mr. Wood kindly accompanied us to the place where he had discovered the specimens in the bed of a small tributary of the Smoky Hill river. This is usually a dry creek, but the recent heavy rains had filled it and had strongly undercut the banks. A close examination of the exposure disclosed several fragments of bones exposed in a thin layer of bluish-gray marl. This material was deposited in a slight depression made by erosion in the Cretaceous chalk which lay immediately below.

"Subsequent excavations revealed the presence of seven or eight skeletons, all crowded within a space ten feet square. These were removed and the large bull has been mounted. In endeavoring to account for the presence of this number of individuals in so small an area it has seemed to me that there is only one explanation. The bone bed lay at the west edge of an old Cretaceous canyon of some 200 yards' width, running north and south, and in a smaller one running east and west. It is supposed that the small herd of bisons was driven by a severe northwest storm along under the northern bluffs of the small east and west canyon. Coming to the intersection of this with the deep north and south canyon they were stopped by the sharp descent, and, huddled under the protecting cliff, finally perished.

"The presence of the arrow-head can be accounted for only on the supposition that it was fixed in the flesh of the animal. The fact that the arrow-head was firmly imbedded in the solid matrix directly under the scapula, at least twelve feet back from the edge of the cliff and under twenty-five feet of deposited soil, precludes the possibility of its having been subsequently introduced."

For comparison with the common *Bison bison* I give, side by side, the measurements of a medium-sized bull of this species and corresponding ones of the extinct form:

	Inches.	*Inches.*
Length from tip of nose to tip of tail	106	122
Height at level of longest neural spine	63	79½
Height at level of hind leg	55	62
Height of fore leg, without scapula	36	37½
Height of hind leg	46	51½
Length of scapula	19⅞	22
Length of pelvis	19⅞	23
Extreme depth of barrel	36	50

	Inches.	Inches.
Extreme width of barrel at tenth rib	22½	25½
Length of humerus	15	15½
Length of femur	16¾	20½
Least circumference of humerus	6	7¾
Least circumference of femur	6¼	6⅝
Diameter of humeroradial joint	3½	4¼
Diameter of femurotibial joint	4⅜	5½
Width of 5th cervical vertebra across transverse processes	5½	5⅞
Length of fore leg, exclusive of humerus	26	29½
Length of hind leg, exclusive of femur	32	36
Diameter of tibiotarsal joint	2⅝	3⅜
Diameter of humerocarpal joint	3¼	4½
Length of longest dorsal spine	18	25
Diameter of humeroradial joint in per cent. of humerus length	23.3	27.4
Diameter of femurotibial joint in per cent. of femur length	26.1	26.8

An examination of these figures will show that the extinct species was considerably larger than the living one, and that it differed materially in some respects from the one with which we are familiar. In the extremes of length and height there are differences of sixteen inches. On the contrary, in the pelvic region there is a variation of only seven inches in height. The unusual development of the neural spines in the dorsal region of course accounts for this excessive height. That there is not, for this reason, a greater slope to the back is explained by the measurements of the two pairs of legs. In *Bison bison* the height of the fore leg is ten inches less than that of the hind leg; in *B. occidentalis* the fore leg is fourteen inches shorter than the hind leg. This strong growth of the posterior members gives the larger bison a racy appearance, and despite the great depth of the body, fifty inches, there is the suggestion of speed and lightness. Possibly this may be due also to the fact that while there is a difference of fourteen inches in the depth of the bodies of the two species, there is a variation of only three inches in width. There is very little difference in the length of the fore leg in the two specimens, but the diameter is materially greater in *B. occidentalis*—a character correlated with the greater weight to be borne. This strengthening of the fore leg is indicated in another way. The diameter of

the humeroradial joint is 23.3 per cent. of the length of the humerus in *B. bison* and 27.4 per cent. in *B. occidentalis,* while a comparison of the femurotibial joint with the femur gives a ratio of 26.1 per cent. in *B. bison* and 26.8 per cent. in *B. occidentalis.*

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THE SPERMATOGENESIS OF XIPHIDIUM FASCIATUM.

BY C. E. McCLUNG.

(Contribution from the Zoölogical Laboratory, No. 178.)

Plate XV.

IN 1898 I described, very briefly, certain stages in the spermatogenesis of *Xiphidium*. This was merely a preliminary paper, and contained nothing beyond an account of certain changes undergone by the accessory chromosome. At the time it was my intention to complete a study of the maturation phenomena in this locustid, but very shortly afterward I encountered in the *Acrididæ* material much better suited to the purpose of my studies and I put the *Xiphidium* preparations aside. Later, when I again turned to the locustids, I found so much larger and clearer cells in *Anabrus* and *Orchesticus* than in *Xiphidium* that it seemed undesirable to use the earlier material except in a comparative way.

That there was a real similarity in the essential features of the process throughout the family I was led to believe by the study of numerous species, and to indicate this most clearly I entitled the paper "The Spermatocyte Divisions of the *Locustidæ*." Notwithstanding this and several specific statements that the descriptions of processes were to apply to the family, including of course *Xiphidium*, with but few exceptions authors and reviewers have based their understanding of my views upon the earlier preliminary paper.

In order, therefore, to avoid further misunderstanding upon the subject, I have recently undertaken a restudy of my *Xiphidium* material, for the purpose of publishing a more complete account of the spermatogenesis of this species. With a broader experience and a better material equipment than I possessed

when I published my first cytological paper, in 1898, I am able to interpret the somewhat obscure phenomena of maturation in this species more accurately than I could then. So far as essentials are concerned, however, I find nothing to change from the accounts in the previous papers, and I shall, for that reason, not go into any great detail in my descriptions. Since other investigators, utilizing similar material, have published accounts that differ from my own in some particulars, I shall, upon these points, speak more extensively. For the sake of completeness I purpose to consider the different generations of cells and to mention the phenomena that each exhibits, particularly those relating to the accessory chromosome.

SPERMATOGONIA.

A determination of the changes experienced by the elements of this generation of cells is very difficult on account of the small size of the cells, the number of chromosomes, and the tendency of the chromosomes to fuse together under the action of the fixing agents. It may be stated with reasonable certainty, however, that the number of chromosomes is the typical one of the family. Of these thirty-three elements the accessory chromosome is by far the most prominent in all the stages of mitosis. The insertion of its fiber is median, and the halves of the dividing chromosome go to the poles of the spindle as U-shaped loops. While the limbs of the U are generally parallel, they are sometimes widely separated, thus forming a V-shaped figure. Because of their length, these parts of the accessory chromosome remain for some time with their ends in the region of the equatorial plate, but they are gradually withdrawn into the general mass of chromatin at the ends of the spindle. (Figs. 1, 2, 3, 4, plate XV.)

The ordinary chromosomes show some little diversity in size, but they do not present favorable conditions for the study of chromosome structure and behavior. Because of their number, and the restrictions placed upon them by the size of the cell, they form an almost solid mass of chromatin in the equatorial plate during the metaphase. Favorable preparations show, however, that the individual elements are distinct and united together only by linin threads. In most cells, on the contrary, the fixation has caused the confluence of all the chromosomes into a plate with occasional apertures such as I described in my former paper ('99, p. 188).

FIRST SPERMATOCYTES.

During the prophase of the first spermatocytes there occur changes in the chromatin elements that make it possible to determine something of their structure and final disposition. With regard to the accessory chromosome I have not much to add to my former descriptions ('99, '02). A spireme stage, such as I figured for *Orchesticus* ('02, fig. 5), appears, but not so clearly as in other genera of the family. This would seem to be a common condition, for it has been recognized in *Locusta* by Otte ('06, p. 531), who apparently was unaware of my earlier account.

Because of the mistaken interpretation by this author of the changes experienced by the accessory chromosome it would seem advisable to present the history of this element somewhat more in detail than I have before done. The long, slender, much coiled thread of the spireme gradually shortens, thickens, and uncoils, the result being to produce, generally, a thread bent upon itself at or near the middle (fig. 5). This double thread may lie straight, but more commonly is convoluted with the free ends in approximation. There is, however, no fixed type form, and almost any shape that a flexible thread may take is represented. As the thread shortens and thickens still further the irregularities of form decrease in number. There is still manifest a tendency for the thread to be bent, usually near the middle, but not infrequently it is straight. Finally, as it approaches the metaphase, it takes on the boomerang form described in my earlier paper ('99, p. 190).

The longitudinal cleavage of the thread is not at any time very apparent, but indications of it are not lacking. The point of interest at this stage is that before the metaphase is reached the rod has almost invariably become almost straight, and never shows the U-shape of the early prophase. It was the failure of Otte to notice this point that led him into error with regard to the division of the accessory chromosome.

The ordinary chromosomes of the prophase show the typical rings, rods and crosses that have now so often been described in insect spermatocytes. There is every reason to believe that they conform to the type of tetrad that is found in other members of the order. No unusual phenomena were observed.

During the metaphase of the first spermatocyte a clearer

conception of the numerical and spatial relations of the chromosomes may be observed than was possible in the earlier stages. At this time it is very apparent from inspections of polar views that the number of ordinary chromosomes is sixteen. There exists also some variation in the sizes of the chromosomes, and two of larger dimensions may always be recognized on the periphery of the equatorial plate, and usually together. The outlines of the chromosomes, in polar view, are approximately circular and no rings are visible. A very compact equatorial plate is formed with little space between the chromosomes. No regular arrangement of the elements was noticeable, except that the larger ones are on the periphery. Occasionally the accessory chromosome, in addition to the sixteen ordinary ones, may be seen in polar view (figs. 6, 7, 8, 9).

A lateral view of the first spermatocyte metaphase shows a series of dumb-bell-shaped chromosomes with now and then a ring-shaped element. There may also be observed lobate chromosomes like a letter E with the middle bar absent. In a large majority of cases the accessory chromosome has already passed to one pole of the spindle without division. The position described in my former paper ('99, p. 190) is unusual, and there can be no question that the accessory chromosome is not divided in the first spermatocyte mitosis (figs. 10, 11). It is impossible to ascertain the character of the chromosome division in this generation of cells, for the elements are almost all of one shape, and offer no means for the determination of planes or axes. In the case of the ring- and E-shaped chromosomes, because of their position, I am inclined to believe that there occurs a segregation division. I hope to present in another paper the evidence for my belief that rings of this character are divided transversely while those that lie in the plane of the equatorial plate, such as I have described for other species of the Orthoptera, are longitudinally cleft. The proof in support of this view seems to me very conclusive, and offers the means for reducing much of the discrepancy that exists in the conclusions of different observers. *Xiphidium*, however, does not afford material suitable for the determination of such points, and I have made no effort to utilize it in this way.

Telophases of the first spermatocyte show the very large accessory chromosome in one daughter-cell and absent from the other. There is evident at this period a marked separation of

the chromatids of this element, usually more prominently at the ends, while at the center they remain in contact. The result is to produce a structure that looks like two U's with their rounded ends in contact. A careful study shows that this is merely an apparent condition, for other cells have the accessory chromosome with the chromatids parallel (fig. 12). The ordinary chromosomes become very loose and granular, but their outlines may still be seen indistinctly.

SECOND SPERMATOCYTES.

The prophase of the second spermatocyte is very brief, apparently, and soon the chromosomes have taken on their homogeneous condition, and have arranged themselves in the equatorial plate. Only rarely, however, do they show the sharp outlines found in chromosomes of the preceding cell generation, but more frequently tend to coalesce somewhat. A polar view of the metaphase shows a compact plate of chromosomes with the large ones on the periphery. In those cells possessing the accessory chromosome there is added this element to the peripheral series. In form the accessory chromosome is V- or U-shaped, with the apex directed toward the center of the spindle (figs. 13, 14, 15). When viewed from the side the V- or U-shaped element is discovered to be double. The ordinary chromosomes are again dumb-bell-shaped (fig. 16).

An inspection of an early anaphase of the second spermatocyte shows that the mantle fibers attach to the center of the chromatid in the accessory chromosome, and division commences therefore at this point. In mid-anaphase the accessory chromosome has accordingly the form of two V's with their apices directed away from each other and toward the poles of the spindle. Still later the separated V's are found with the other chromosomes at the poles of the spindle. Even in the telophase they remain in this form and position after the other chromosomes have fused together in a mass. The plane of separation is unquestionably the longitudinal cleft, visible most prominently in the telophase of the first spermatocyte. In those second spermatocytes from which the accessory chromosome is absent, the chromatin elements divide almost synchronously and pass to the pole of the spindle in a mass. The presence of the accessory chromosome, which divides later than the other chromosomes, tends to retard division on its side of

the plate, and the daughter groups are therefore inclined to each other instead of being parallel. No other peculiarities in the division of the ordinary chromosomes presented themselves. (Figs. 17, 18, 19, 20.)

GENERAL CONSIDERATIONS.

The points of interest in the spermatogenesis of *Xiphidium* relate to the accessory chromosome, and I shall therefore first briefly summarize its history and then speak of the accounts of other investigators.

It is to be noted that the accessory chromosome is a single, very large spermatogonial chromosome that enters the prophase of the first spermatocyte without undergoing any extensive separation of its chromomeres. While it forms a thread, this is always denser and more compact than the general spireme. The result is that the element always stains strongly, after the manner of metaphase chromosomes. It is thus made very conspicuous in its position on the periphery of the nucleus. It passes through a variety of forms, but finally enters the metaphase of the first spermatocyte as a bent rod, and in this form passes *undivided* to one pole of the spindle. The result is to produce two types of second spermatocytes.

In the metaphase of the second spermatocyte the accessory chromosome takes its place in the equatorial plate and is there divided along the plane of its early longitudinal cleavage—an equation division. From each first spermatocyte there are accordingly produced four spermatids, two of which possess an accessory chromosome while the other two are without it. These results are in accordance with my more extensive work ('02) upon other members of the same family, and vary at points from the preliminary account upon *Xiphidium*.

The only other investigators that have concerned themselves with the spermatogenesis of the locustids are dé Sinety ('01), Stevens ('05), and Otte ('06). The work of Sabatier ('90) dealt only with the transformation stages, and so does not concern the present discussion. The results of dé Sinety and Stevens in the main agree with mine; those of Otte are radically different in essentials. I wish here briefly to note the work of the latter author upon the accessory chromosome only. I hope to consider the maturation divisions of insects in detail in a subsequent paper.

I consider the work of Otte entirely erroneous so far as it relates to the method of division of the accessory chromosome in the second spermatocyte mitosis, for it is widely at variance with what I have found in the large number of species of the Orthoptera that I have examined. The figures that he presents in his preliminary paper ('06) are not at all convincing, and I am fully persuaded that a more thorough study will convince him that his identification of the longitudinal split of the accessory chromosome in the second spermatocyte metaphase with the space between the bent halves of the rod in the prophase of the first spermatocyte is a mistake. That Otte's interpretation could not apply to *Xiphidium* is evident from an inspection of the second spermatocyte during the division of the accessory chromosome (fig. 17). The element here is in the shape of a V with the fibers attached at the angle. It is in this form that Otte conceives the break across the rod to occur, but instead the whole bent structure is split along its length into duplicate V-shaped halves. There is no possibility of mistaking the longitudinal split for a space between the halves of a bent rod. In those forms where the fibers attach at the ends of the chromosomes there would be more of a possibility of such confusion, but even there a sufficiently complete series of stages will make clear the presence of the longitudinal cleavage and its identity with the plane of separation in the second spermatocyte metaphase.

It is unnecessary to point out that Otte's account does not agree with the great majority of observations upon other forms, and that, on the theoretical side, it attacks the hypothesis of the individuality of the chromosomes, unless indeed he would assume that the accessory chromosome is bivalent. It is very probable that he does not make this assumption, for all the other chromosomes are described as being transversely divided. So far as I know, the only writer who regards the accessory chromosome as bivalent in the Orthoptera is Montgomery, who made a superficial study of this structure in *Syrbula*, an acridian. That he is in error on this point is shown by the work of Robertson (in publication) upon the same genus.

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THE CHROMOSOME COMPLEX OF MELANOPLUS BIVITTATUS SAY.

BY NADINE NOWLIN.

(Contribution from the Zoölogical Laboratory, No. 179.)

Plates XVI, XVII.

THAT certain chromosomes are distinct individuals and maintain their identity through the different generations from spermatogonia to spermatids there can now be no doubt. The work on the accessory chromosome, and very recently that on the idiochromosomes, has furnished specific evidence of this. Moreover, the complex as a whole has been studied and the individuality of most of the chromosomes of the group has been fairly well established. For instance, Sutton ('02) carefully measured the chromosomes of the *Brachystola magna* complex. Baumgartner ('04), in his work on the cricket germ-cell, has laid stress on the individuality as expressed in form, and Boveri ('02) showed experimentally a difference in function. Perhaps the most conclusive evidence of chromosome individuality is the occurrence of the same number in an entire family, as found by McClung ('05) in the *Acrididæ*.

Chromosomes may exhibit individuality then (1) in size, (2) in form, (3) in function, (4) in constancy in number. To these might now be added another, (5) individuality expressed in grouping. McClung ('05), in his recent work on certain species of *Hesperotettix* and *Mermiria,* discovered a grouping or association of definite chromosomes that holds not only for the individuals of a species, but for all the species of the genus thus far investigated. Such an aggregation of chromosomes he calls a *multiple,* and by careful measurement of the elements of the multiple he finds that the specific difference

is one of size. The importance of the discovery of the multiple chromosome is very evident: the elements composing it can be followed through the different species without the shadow of a doubt, which is most important in determining its bearing on heredity.*

The crying need just now is for a better understanding of the chromosome complex, not only of one species but of many species of a genus, so that careful comparisons can be made. This is the first step toward a correlation of chromosomes and body characters. If chromosomes are definite masses endowed with the transmission of characteristics, then the complex should not differ greatly in the various species of a genus.

This paper is the first of a series which will have for its object the investigation of the chromosome complex of the genus *Melanoplus*, and forms part of a plan of investigation into the acrididean complex which has been outlined by Dr. C. E. McClung. The genus *Melanoplus* is a large and variable one, while *Hesperotettix* is small and well defined. Since these belong to the same group, the *Melanopli*, the nature of the complex may be correlated with the generic variations.

A species of *Melanoplus* has been investigated by Wilcox ('95), but his aims were somewhat different from those of the present paper, as were his results. The old idea was that an understanding of the complex of one species meant not only knowledge of the whole genus but of practically all animals. Thus, believing that the first division in *Melanoplus femur-rubrum* is transverse, he concludes that this method of division is general. In such a well-defined group as *Hesperotettix* (McClung, '05) it was found that what is true for one species may be true for all; but in *Melanoplus*, a large and variable group, there are probably variations to be found in size, in chromosome grouping, and in various other respects. The object of this series is to study and compare these variations. As to division, however, no discrepancies have been discovered. McClung found, contrary to Wilcox, that the first division in *Melanoplus femur-rubrum* is longitudinal, and my investigations on *M. bivittatus* supports this view.

* Since this paper was written, Doctor Wilson ('07) has found multiples in the Hemiptera.

MATERIAL AND METHODS.

The form under consideration, *Melanoplus bivittatus* Say, belonging to that group of hoppers called *Acridiinæ*, was collected in Graham county, western Kansas, in the summer of 1904, and forms part of an extensive collection brought together for the purpose of such studies as the present. For both material and direction in this work I am indebted to Dr. C. E. McClung.

The testes were fixed in Flemming's fluid and stained in Heidenhain's iron-hæmatoxylin. Sections were cut six micra in thickness.

OBSERVATIONS.

The germ-cells of *Melanoplus*, as of all other genera of the *Acrididæ* thus far investigated, have twenty-three spermatogonial chromosomes, twenty-two of which may be paired and the twenty-third without a mate, the typical accessory of McClung. Due to the great crowding in the spermatogonia the exact form of the individual chromosomes is difficult to see, but the general shape is that of a rod. The smallest pair, however, is without exception spherical. The chromosomes are arranged radially around an open center in which occasionally lie from one to two chromosomes (fig. 1), and can with a fair degree of accuracy be paired. The complex is composed of a graduated series of chromosomes whose size relations are well shown in plate XVII.

In this material the lateral view of the first spermatocyte metaphase is more satisfactory for a comparative study of the chromosomes than the polar view. Since practically all the chromosomes form like tetrads, they cannot with any accuracy be distinguished by form, so here the size test becomes necessary. A glance at figures 3A and 3B will show the great variation in size of the chromosomes of a complex.

For convenience it has been decided to number the chromosomes according to their size, calling the smallest No. 1 (fig. 3). This small chromosome assumes the form of a cross at one stage in its division but completes its changes before reaching the metaphase. It has never been observed in any but spherical form here. There is another chromosome which seems to do the same: No. 11, in the metaphase, is always pulled out into the long rod-like form. Running down column 11, plate XVII, one sees this without exception. No. 12 is the largest of

the group, and in its fully extended state measures about eight times the length of the smallest. This chromosome stands out prominently through all the generations from spermatogonia to spermatids and will serve excellently for comparison in other species. Chromosome No. 10 is characterized by the form of a ring and is easily distinguished in the first division, both in a lateral and a polar view. The single ring seems to be constant for this species. Occasionally the largest two chromosomes assume the ring shape (fig. 9), and on the other hand cells are found which contain no rings (fig. 6). The formation of the ring is exactly like the other chromosomes of this group, a bivalent chromosome possessing, when it comes into the spindle, a longitudinal split along which it divides in the first spermatocyte. The chromosomes numbered 9, 8, 7, show a gradual diminution in size but have no peculiarity of form to distinguish them. Chromosome No. 6 does not differ in form, but, as is characteristic of the accessory, can be recognized by its eccentric position in the spindle. The next four chromosomes are not distinguishable by shape, but No. 1 is always spherical. No. 2 is usually similar to No. 1 in form but slightly larger, and is sometimes found in the form of a cross (pl. XVII, cell F, row 2).

There are, then, five chromosomes of this group that can be recognized with certainty in the spermatocyte generations: No. 1, the small spherical; No. 6, the accessory; No. 10, the ring; No. 11, the long chromosome, always fully extended and next largest, and No. 12, the largest chromosome of the complex.

Despite the crowding in the spermatogonia, two pairs of chromosomes, No. 12 and No. 1 (fig. 1), can be easily distinguished; the others are doubtful.

The chromosomes divide longitudinally in the first division, with the exception of the accessory, which passes undivided to one pole. As some dispute has arisen concerning this division it might not be amiss to follow out briefly the behavior of the chromosomes from the spermatogonial stage. Here we find the chromosomes often showing the longitudinal split (fig. 1, chr. 9). In the early growth stages the spireme is distinctly split, and even after segmenting and much condensing this division is still visible. Very soon after synapsis the bivalent chromosome begins to separate into halves along the longi-

tudinal split. One program of movement is closely adhered to in every case. The longitudinal split runs from one end of the bivalent chromosome to the other, and separation along this split begins at the place of union of the two univalent elements, as shown in figure 2, chromosome 4. It is in this condition that the chromosomes sometimes enter the spindle, their long axis, or the longitudinal split, parallel with the equator (pl. XVII, cell G, row 7). More often, however, division has continued to the point where the arms of the cross are equal (pl. 2, cell A, row 8), or even farther, as in cell A, row 9. The chromosomes of this complex divide very irregularly as to time, some having almost completed the separation while others are but beginning. This variation is seen in plate XVII, cell G. Chromosome 11 seems to be precocious. The ring chromosome, No. 10, divides slowly, as might be expected, and, like the others, shows the first division to be longitudinal. Its behavior is entirely different from such rings as are found in the beetles, where the two bivalent elements separate in the first spermatocyte (Stevens, '06; Nowlin, '06).

The ring has some significance in this material—not that its occurrence is unique, but because of the constancy of this form of chromosome for different species. A single ring seems to be constant for *Melanoplus bivittatus,* while in one of the Tryxalines, *Syrbula admirablis,* now under investigation by Mr. Robertson, there are five rings.

There is little difficulty in seeing that a chromosome which enters the spindle with its longitudinal split at right angles to the long axis of the spindle divides longitudinally in the first spermatocyte. The spindle fibres are attached at right angles to the split (pl. XVII, cell G, row 7) and consequently pull the halves apart along this split. But a chromosome like No. 12, which enters the spindle with its longitudinal split parallel with the long axis, may cause confusion. On account of its great size this chromosome can be easily followed through the different generations. In a polar spermatogonial view (fig. 1, chr. 12) it is seen to be long and rod-shaped, about eight times the volume of the smallest, No. 1. In the early prophase we recognize it again by the great size (fig. 2). In the late prophase we see it in the form of a cross (fig. 8), and in metaphase (fig. 10A, chr. 12) again as a rod. There is but one explanation: the chromosome during the prophase begins to

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THE CHROMOSOME COMPLEX OF SYRBULA ADMIRABILIS.

BY W. R. B. ROBERTSON.

(Contribution from the Zoölogical Laboratory, No. 180.)

Submitted in partial fulfillment of the requirements for the degree of Master of Arts.

Plates XVIII to XXII.

THIS paper is the first of a series by the author, and one of a larger series from this department, in which will be recorded the attempts to find the relation existing between body characters and germ-cell structure. Much detail has been necessary in this preliminary work in order to lay a foundation for future comparisons between the four species of *Syrbula*, and also to clear up the misunderstandings concerning the phenomena of maturation in this genus that have been brought about by Montgomery ('05) in his investigations upon *Syrbula acuticornis*. This latter purpose is of particular importance since Montgomery's findings form the only recorded exception to the rule of uniformity in the entire Acrididæan family.

Syrbula admirabilis belongs to the short-horned grasshopper family *Acrididæ* and to the sub-family *Truxalinæ*. It is found most commonly in the central part of the United States. The three other species, *acuticornis, fusca-vittata,* and *montezuma,* are southern in their habitat, occurring chiefly in the southwestern states and northern Mexico.

The material for these observations was obtained in Dickinson county, Kansas, during July, 1906. Flemming's fluid was used for fixation. Heidenhain's iron-hæmatoxylin was found best for staining during the metaphase of mitosis and Flemming's tricolor the most desirable for all other stages, especially where it was desired to distinguish between the accessory chromosome and the structures commonly called nu-

cleoli. The ribbons were cut usually twelve micra thick, in order to make it possible for a whole nucleus to be seen in one section, thus avoiding the uncertainties arising in the counting of chromosomes, etc., from the use of fragmentary nuclei.

METAPHASE OF THE SPERMATOGONIA.

For convenience, the chromosomes have been numbered according to their size, from smallest to largest, the system being based upon the relative sizes of the twelve chromosomes in the first spermatocyte. In polar views of the spermatogonial metaphase twenty-three chromosomes can be very clearly seen, and it is apparent, as Sutton and Montgomery have pointed out, that they occur in pairs. They have therefore been numbered in duplicate according to similarity of size. In doing this it is assumed that the largest two of the twenty-three, the No. 12's, will conjugate and form the largest, No. 12, of the twelve first spermatocyte chromosomes; that the next largest two, No. 11's, of the spermatogonia will form the one next largest, No. 11, of the spermatocyte; and so on for each pair. In this way the twenty-three chromosomes of a spermatogonium may be grouped into a series of eleven pairs and one odd unpaired member. The odd one is probably the assessory chromosome, although we cannot be absolutely sure here which one of the complex it is. This much, however, can be said; there are three chromosomes, the two No. 10's and No. 5 (figs. 1, 2, 4 and 6), which are of about the same size. In synapsis two of these will unite, and, of course, one of them must be left unpaired (Wilson, '05). This, then, is thought to be the accessory. It corresponds in size with the accessory of the first spermatocyte, where there can be no doubt as to its identity.

Six polar views were drawn, four of which, figures 1-4, are from one animal and one apiece, figures 5 and 6, from two other animals. Of the chromosomes in each cell there can be distinguished three large pairs, the 12's, 11's and 10's (Montgomery, '05); an accessory No. 5, which, as before said, is about the size of the No. 10's; three pairs of very small ones, and five pairs ranging in size between the largest and the smallest. Usually the No. 4's and 6's may be recognized, but the 7's, 8's and 9's, being very much alike in size, can hardly be told apart. In the drawings it is not possible in every case to show the real length or size of the chromosomes, since they

do not always lie in a plane parallel with the field of the objective. The image is thus foreshortened. The proper size relations, however, are quite apparent to the eye of the observer as he examines the chromosomes by different focusings.

In mitosis every chromosome divides longitudinally. The splitting seems to have already taken place when the elements first appear in the equatorial plate. (Figs. 1-4.) The separation of the halves begins at that end of the chromosome which is turned towards the center of the plate (fig. 6), the end to which the fibers from each pole of the spindle are attached. It seems sometimes that the halves are moving apart at the outer end of the chromosome but this only indicates that the element is already split. The real separation of the halves begins at the inner end.

At this point it may be well to call attention to the position of the members of a pair in the plate. The two *may* lie together but it does not follow that they always do so. In the case of the smaller chromosomes the members of a pair are quite often on entirely opposite sides of the plate, or on the same side but with several other chromosomes between them. Compare figure 6, chromosomes 4, 4 and 3, 3; and figure 3, chromosomes 3, 3 and 2, 2. In figure 6, No. 4 on the right side has no member near it that at all corresponds in size, and yet we know that it will unite only with one which is its equal. We know this from the fact that the halves of a tetrad are always alike in size, length and diameter. The only chromosomes with which this one can at all conjugate are on the opposite side of the plate.

THE ACCESSORY CHROMOSOME AND THE NUCLEOLI.

In studying the resting stages of the spermatogonial and spermatocyte nuclei the chief object has been to trace the accessory, to see if there is any connection between it and the nucleolar-like structures that are always present in these stages of the nucleus. The earliest of the secondary spermatogonial nuclei that were found (figs. 7, 8 and 9) showed the presence of these nucleolar structures. With Flemming's tricolor they take safranin, like chromosomes in the condensed or homogeneous condition (figs. 7-10). Distinct from the nucleoli the accessory chromosome lies at one side of the nucleus, separated from the rest of the chromosomes in a sac or vesicle of its own (figs. 7-11). It shows no evidence of being

a paired structure as Montgomery ('05) suggested. In late anaphases and early prophases of the spermatogonia the other chromosomes also seem each to be enclosed, more or less, in separate sacs or pouches, which are, however, in communication with each other by means of the larger cavity of the nucleus into which they all open. These sacculations are, however, not nearly so prominent as that of the accessory. These observations agree with the conditions that Sutton ('00) found in *Brachystola magna*. In the earlier cells the accessory shows that it is reticular in structure, like other chromosomes, though not inclined to open out so much as they. The nucleoli in these cells (fig. 7) do not stain so intensely as they do afterwards.

Figures 8 and 9 represent a somewhat later stage, possibly the telophase between the last two spermatogonial divisions. The reticular structure of the accessory still persists. It is much like the other chromosomes, but just a little more regular in outline and more condensed. The membrane or sac enclosing the accessory in figure 8 seems to extend into the center of the nucleus, but this is only apparent. Instead it lies in the upper part, extending over the inner side of the upper wall. Figure 9 is a cell from the same cyst, showing a cross-section of the accessory in its sac. In focusing through the cell from top to bottom it can be seen without doubt that this is the same structure found in the preceding cell. The other chromosomes in this cell appear also in cross-section. Two nucleoli seem to be present in every cell of the cyst. They are somewhat larger than in figure 7 and stain more intensely.

After the last spermatogonial division the nucleus is at its smallest volume. The chromosomes, except the accessory, loosen up and take on a reticular condition. The accessory retains its homogeneous and more or less condensed state, staining red with the tricolor (fig. 10). It becomes very irregular in outline, thus indicating a tendency to behave like the other chromosomes. The nucleoli are present and stain red, though not so intensely as does the accessory. Figure 11 is a still later stage, where the chromatin has become very much loosened. The nucleoli seem to share this same condition of loosening, as they are stained very pale, almost a violet, but instead of becoming granular they continue to be homogeneous.

From figure 12 on, the nuclei belong to the spermato-

cyte stages, as shown by their increased size. The chromatin of the ordinary chromosomes seems to be strung out in granules along the linin threads, giving a somewhat bead-like appearance. The accessory, instead of being elongated and stretched upon the nuclear wall as before, seems now to be massed into a sort of irregular lump, which, however, still clings to the wall. The nucleoli here stain deeply with the safranin. In each of the four cells (figs. 12-15), all of which are from the same cyst, two nucleoli seem still to be present. Sometimes they lie very close together, even in contact (figs. 14 and 15). In addition there is in some cells, but not in every one, another body (*K*, figs. 11, 12, 13) somewhat similar to the others but more irregular and diffuse than they. It may possibly be a portion of a chromosome that has not entirely disintegrated or loosened up since the last mitosis, or it may be a spermatocyte chromosome condensing ahead of its fellows. At the proximal end of this follicle, where the cells are older and farther advanced, and from which figures 10-15 were taken, there is present only a single nucleolar structure, besides the accessory, in each nucleus. The nuclei here, however, were not very well stained, so figures 16-22 were taken from the proximal part of another follicle of the same testis. They show the same stages as the preceding follicle, but much better stained.

In the spermatogonia, and in the earlier stages of the growth period, as I have before indicated, there appear to be two nucleolar bodies present. In the later growth stages (figs. 16-26) there is only one that is at all a permanent structure. This is about equal in size to two of the former nucleoli. (Compare figures 14, 15 and 18.) From these observations it seems possible that there may be a conjugation of these structures in the earlier stages to form the single structure of the later stages. But the proof of the point will have to be established by further investigation. The single nucleolar body, as it occurs in the later stage, may be distinguished from the accessory in three ways: (*a*) by its smaller size; (*b*) by the fact that it usually lies nearer the center of the nucleus, not against the nuclear wall, as does the accessory; and (*c*) because in the later stages it gradually loses its ability to hold the safranin stain (figs. 20-26). The time at which the body begins to lose its staining ability seems to

vary. Possibly this is due to variations in the extraction of the stain during the clearing process. The nucleolus in figures 16-19 stains as deeply as does the accessory. In some cysts, where the chromosomes are in the extremely loose or early prophase stage, it may be stained very lightly (figs. 20-22)—a violet instead of a safranin color—while in other cysts, where the chromosomes are in a much more advanced condition, it may still be found staining as homogeneously and as deeply as the accessory, though much more irregular in outline than the latter. However, by the time that the chromosomes begin to condense it has almost entirely lost its color, as in figure 24. Finally, at the stage of figure 26, we find it nothing but a pale-yellow or colorless mass. Along with the loss of staining capacity comes a slight decrease in volume. But although it may appear irregular in outline and colorless, it always retains its homogeneous structure. A count of the chromosomes at the stage of figure 26 was made, which showed eleven ordinary chromosomes, the accessory and one nucleolus. For this reason, as well as others, we are quite safe in contending that this permanent structure is not a chromosome but a nucleolus, and we feel still more certain that it is not a second accessory or heterochromosome as Montgomery has described it for *Syrbula.*

In figure 19 is represented a second densely staining body (*t*). This seems to be merely the end of a spermatocyte chromosome, as indicated by the figure, that is beginning to condense ahead of its fellows. It cannot be typical of the cyst, for no other cells were found in the cyst containing an element that could be considered homologous to this. Possibly it is the same structure as seen in *K*, figures 11, 12 and 13. There are present at times small globules, such as *P*, figures 16 and 18. They are by no means constant for every cell and therefore have been disregarded.

Turning to the accessory again, we find it changing from the smooth, compact, lumpy condition of figures 16-19 to a flat, extended condition as in figures 20-22. Sometimes in this state it is extremely ragged (fig. 20) and may be vacuolated (fig. 21), as is often the case in the earlier (lump) condition (fig. 18). In the stage following (figs. 23-28), the accessory as usual manifests its tendency to behave like other chromosomes, by evolving out of the flat, somewhat fenestrated mass

of such as figure 20 a coiled spireme similar to what McClung ('02) has described for the *Locustidæ.* At first this spireme is very irregular and difficult to outline (fig. 23), but later it becomes as clear cut as any ordinary metaphase chromosome, though much more coiled (figs. 24, 25). It gradually shortens and thickens, as shown in 26, 27 and 28, and finally arrives at the metaphase as a short, compact, almost straight rod (figs. 30-36). The accessories of figure 25 are from nuclei of the cyst which contains figure 24, those of figure 27 from that containing figure 26, and those of figure 28 from the cells of a cyst that is still farther advanced than any of these. As well as showing the gradual shortening and thickening that the accessory undergoes, these figures show the many shapes that it may assume in various nuclei that are at the same stage in development. From the time that it enters the spireme condition it becomes perfectly smooth in contour, contrary to what we find in many *Acrididæ,* where in the late prophase or the metaphase it is often woolly. No indication of a longitudinal split has been noticed in this spireme condition, although it might be expected to be present. And lastly, there is no evidence of a transverse constriction such as Montgomery claims for *S. acuticornis.*

We have now traced the accessory from the resting period of the spermatogonia through to the spermatocytes. At times there was difficulty in recognizing it, especially in the spermatogonial prophase, where it had a tendency to form a network like the other chromosomes, but even there we were able to tell it by its peculiar vesicle. After the last spermatogonial division it was always recognizable by its condensed, homogeneous appearance and by its peculiar position, applied close against the inner side of the nuclear membrane. During all this time there has been no indication of its being a paired or bivalent structure. We have seen no segmentation of the spireme in the vesicle stage of the spermatogonia, no paired condition in the spermatogonial metaphase where the chromosome number was odd, not even, and no paired condition in the growth period following the last spermatogonial division, where the additional chromatin-like structure present was found to be a nucleolus, not a chromosome. And lastly, we have seen no transverse constriction or a bending at any particular place that would in any way indicate the bivalency

of this element. To the contrary, we have found it always and under all conditions an independent, odd, unpaired and univalent member of the chromosome complex.

THE CHROMOSOMES IN THE SPERMATOCYTES.

It is at this stage in the course of the development of the germ-cells that the characteristics of the various chromosomes of the complex stand out most prominently. The drawings were made principally from polar views of the cell-plate. A few lateral views were drawn to show in particular the habit of the accessory. To understand the shapes assumed by the various chromosomes during the mitotic stages attention should be called to the forms they assume in the prophase just before the formation of the mitotic figure. Tetrad formation has already received such a thorough discussion by McClung ('00 and '02) that it seems unnecessary to say anything further about it, but the mistakes of some recent workers along this line make it again necessary to bring up the subject. In figures 26 and 29 are shown the different forms of rods, rings, crosses, V's, Y's, etc., that may be seen in the late prophase stages. As a study of the figures will show, "all of these shapes may be reduced to a single type, that of a rod with one longitudinal and one cross division." Every rod is formed by the end-to-end union of two homologous spermatogonial chromosomes. In this union like ends always unite with like ends, *i. e.*, proximal with proximal and distal with distal, if the latter unite. By "proximal" is meant that end of the chromosome which is always turned towards the center of the cell-plate and to which the spindle fibers are attached, whether in spermatogonia or spermatocytes (figs. 1-6 and 30-36). By "distal" of course is meant the opposite or outer end. In this conjugation of the spermatogonial pairs to form the tetrads the proximal ends always unite, but the distal may or may not. If they do there are formed rings, figure 8's, etc. If they bend toward each other but do not unite there occur partially closed rings, V's, bent rods, or kidney shapes. If the members of the pair lie fully extended there is produced simply a straight rod.

At the point where the members of the pair always unite, the proximal end, the chromatids (halves of the spermatogonial chromosomes) may quite often have started to move outward in the plane of the cross-division (*XX* in fig. 29).

This usually gives an enlargement at this point, or, if far enough along, a transverse extension. The point at which the distal ends unite, when they do so in forming a ring, is often marked by a constriction. The signs *XX* mark the points at which the spindle fibers will be attached, and also where the future cross or reduction division in the second spermatocytes will take place. The degree to which the chromatids have moved along the transverse axis determines the shape of the tetrad. In this way we account for the various crosses that are found. If the chromatids have moved out very far, the long axis of the cross may be in the transverse direction. This condition may be seen in the long drawn-out chromosomes of the lateral views (figs. 34 and 35). Exactly the same phenomena may occur in the case of the ring forms. The only difference with these is that the ends of the longitudinal or primary axis of the cross are turned over toward each other and united end to end, thus forming a ring. As the arms of the transverse axis elongate or pull out, the ring (arms of the longitudinal axis) keeps getting smaller (fig. 29) until there is produced the same result as with the cross forms. One of these rings acting in this manner is seen in figure 29. From the figures in 29 we are led to believe that the greater part of this gliding of the chromatids from the longitudinal to the transverse axis is done while the chromosomes are still in the prophase condition, before they enter the metaphase and have had a chance to come under the influence of the spindle fibers. This seems to indicate that chromosomes are to a certain extent automatic in the division process. Lastly, a word should be said in regard to the puzzling appearance of some of the strictly cross forms. The angles that the limbs of the cross may have with each other, depending upon the position of the tetrad in the cell, often give to such chromosomes the appearance of K's, Y's, etc., but with careful observation it may easily be seen that they are of the cross type. The figures themselves (fig. 29) furnish a better explanation of this than is possible by the use of words.

It is from prophase chromosomes such as we have been describing that the metaphase chromosomes of the first spermatocyte have been derived. The only difference is that the latter are much more condensed, even so much so that the longitudinal split is no longer visible. But the same four

parts are present and in the same relation to each other. Of course now the chromosomes have the spindle fibers attached to them at the synaptic points (*XX*). In the arrangements of the group in the metaphase plate, the larger chromosomes, the rings and bent rods, usually lie on the outside and the smaller chromosomes nearer the center. The number in the first spermatocyte, without a single exception, was found to be twelve. Of the group, the three or four extremely large members, the three small ones and the accessory (No. 5) may quite readily be recognized. In polar views of the cell-plate the accessory is very often seen in cross-section or from a very oblique side view. But it can usually be recognized with very little trouble, since it almost always lies near the periphery of the plate and shows no tendency toward division at this time.

Figures 34, 35 and 36 are lateral views, showing the accessory in its characteristic position. All the other chromosomes are in the act of dividing. It is starting ahead of them, undivided, to one of the poles. It may at one time have been in the equatorial plate along with the others, but now, as may be seen by the figures, it is moving out. In a close examination of the spindle it is found that each of the ordinary chromosomes is attached by means of a single fiber to each pole. The fiber, as before said, fixes itself at the point (*X*) on the chromosome where the future reductional division will take place. In the case of the accessory there is only one fiber, that connecting it with the pole towards which it is traveling. Its opposite end is entirely free of fibers.

In figures 37-39, anaphases of the first division, there is clear evidence that the accessory does not divide but passes over, as it is, to one of the resulting daughter-cells. Figure 37 shows all of the remaining chromosomes dividing or divided. The largest one, chromosome No. 12, seems to be much twisted, but nevertheless the four parts to it may be easily made out. The chromosomes in this drawing have been displaced somewhat to right and left in order to show them more clearly. They occupy, however, the same relative position with respect to each other that they did in the cell, although spread out over a greater area. Figures 38 and 39 are still later anaphases, showing eleven dyads at one pole and their eleven mates, plus the accessory, at the other. The halves of the accessory (No. 5, figs. 38 and 39) as it nears the pole seem to be inclined to

fly apart at the distal end, as do the dyads of the other chromosomes. This seems to indicate that the accessory was probably split like the ordinary chromosomes before entering the metaphase. These cells are typical of whole cysts that may be found showing the unequal distribution of the chromosomes to the daughter-cells of the first spermatocytes, thus giving us the two forms of the second spermatocytes.

In polar views of the second spermatocyte metaphase (figs. 40 and 41), half of the cells in a cyst show the twelve and half the eleven dyads.* In these figures a good clew may be obtained as to size relations, for the chromosomes lie spread out flat in the plate, and since all of them are double rods of about the same diameter their relative size is merely a question of length. Of course the size of the accessory here, in comparison with the other chromosomes, is just twice as great as the first spermatocyte, because all the chromosomes here except the accessory are just one-half as large as they were in the preceding mitosis. In figure 41, where there is no accessory, the relative sizes cannot be mistaken. There are the three extremely large members, Nos. 12, 11 and 10, the three small ones, Nos. 1, 2 and 3, and a series 4, 6, 7, 8 and 9 coming between these, many of which are often indistinguishable from each other.

In figures 42 to 45 we have anaphases of the second spermatocyte, showing the division of the dyads in the two kinds of cells. Nos. 42 and 43 are complete cells, showing the division of those that have eleven, and 44, 44*a* and 45 of those that have twelve dyads.* A fragment of the lower halves of each of the latter had to be sought in the next section, but there was no doubt as to the number of chromosomes being twelve. The accessory may be recognized in 44 and 45 by its somewhat greater diameter and more intense staining propensities. In conclusion, it may therefore be said that one-half of the spermatozoa receive eleven chromosomes plus the accessory and the other half eleven and no accessory.

COMPARISON OF SYRBULA ADMIRABILIS WITH SYRBULA ACUTICORNIS.

The first point to be considered is in regard to the number of chromosomes. In this *acuticornis* seems to be different from the whole family *Acrididæ*. So far, with a few exceptions, there has been recorded for the family twenty-three

* The unnumbered elements in figures 41 and 45 are the result of accident in preparing the drawing. They are not present in the cells.

chromosomes in the spermatogonia and twelve in the first spermatocyte. In most cases where exceptions occurred it has been found that they were only apparent, the full number in each case being present, but with some two or three of the members joined together, forming a multiple chromosome. *Stenobothrus*, a form recently studied by McClung, has apparently twenty-one in the spermatogonia and ten or eleven in the first spermatocyte. The other exception is a subfamily of the *Acrididæ*, the *Tettigidæ*. I have now on hand slides of this form showing thirteen chromosomes in the spermatogonia and seven in the first spermatocyte. The variation here need not, however, cause us worry, when we recall how the *Tettigidæ* differ from the rest of the *Acrididæ* in external characters. It seems more reasonable that they should be considered a family by themselves, in rank equal with the *Locustidæ*, *Gryllidæ* and the *Acrididæ*, than as a subfamily of the last group. The number for the family seems therefore to be constant. Montgomery, however, seems to be in doubt in regard to the number of the chromosomes in *acuticornis*. According to his observations some individuals have twelve, while others of the same species have ten, and in the spermatogonia instead of twenty-three he finds but twenty. Being unable to decide whether the two numbers in the spermatocytes "were due to individual variation or to the presence of two subspecies within the species," he chose to base his conclusions upon the germ-cells of a single individual. It would have been much better to have studied the cells of several individuals and then to have made use of that merely which was typical for the species. In the spermatogonia he "found only two clear polar views of the metaphase, each showing twenty chromosomes." Now the evidence furnished by two cells is not enough upon which to base any important conclusion. There is too much danger of not having the full number present that belong in the cell. Very often a part of the number must be sought in the next section; or sometimes one or two which may have happened to lie on the top or bottom of the section have been dropped out or displaced. He has one other drawing, a late anaphase of the last spermatogonial division, showing the twenty, but at best any late anaphase is a doubtful quantity. In the first spermatocyte he finds ten chromosomes, but he has given not even a single drawing showing this number.

With the mistakes of Montgomery in mind I have been careful in this work to use the testes of several individuals, about a dozen or more, and to examine and draw from these as many cells as time would permit, showing the full number of the chromosomes. The sections were cut twelve micra thick, and so in a great many instances I have been able to show cells that contained in a single section the whole number of chromosomes. In every case so far examined the numbers for the first spermatocyte and the spermatogonia have been respectively twelve and twenty-three. In addition to this the cells of *Syrbula fusca-vittata*, another species of the same genus that was examined, showed the same numbers. In view of these facts *Syrbula acuticornis* either must be radically different in germ-cell structure from the other members of the genus or there must be some mistake in the reported numbers. Until some of the material is inspected I am inclined to believe the latter, for Montgomery in his meager illustrations has not furnished proof sufficient to establish the truth of his statements.

The next point in which we shall have to disagree with Montgomery is in regard to the formation and division of the tetrads. The conditions as they occur in *Syrbula admirabilis* have already been described. There remains to be considered the differing conditions that he has described for *acuticornis*, and concerning which I believe he was mistaken. It seems that his first object here was primarily to find evidence to confirm his old "pre-reduction" theory, and accordingly he has forced the interpretation of every phenomenon, whenever possible, to its support. Generally speaking, it matters little whether reduction occurs in the first or the second maturation division, for the result is the same either way. In fact, some species of the *Acrididæ* (McClung, '05) show that both reduction and equation divisions among ordinary chromosomes may occur at the same time.

As before shown, all the tetrads in the late prophase and in the metaphase may be reduced to a common type—that of a rod with one longitudinal and one transverse division. The latter marks the point at which the proximal ends of the univalent spermatogonial chromosomes have come together to form the bivalent tetrad. This rod has the ability, as before explained, to change its axis from a longitudinal to a transverse direction. The former it possesses in the beginning of synapsis and the latter in the final stages of the first sperma-

tocyte mitosis, just before the separation of the dyads. The cross form is merely a transition stage that the rod passes through in its change from one axis to the other. Montgomery says that "very rarely have the chromosomes an X-shape." By "X" he probably means the cross shape. He is mistaken in this, for the X or cross is a form that may always be seen in any cell during the late prophase and the metaphase. He has but one drawing (his fig. 31) showing a cross form, and for that he gives no explanation whatever. From the way he has drawn it one would judge that the univalent chromosomes which constitute it were in conjunction at the middle of their length instead of at the ends. But this view of the cross cannot be brought into agreement with the form that the earlier more open crosses of the prophase show (figs. 26, 29), where the four parts to the tetrad, the chromatids, may with little difficulty be traced from arm to arm, where it may be seen that in this cross every chromatid forms a part of two arms and no two of the chromatids continue together throughout their whole length (cf. fig. 29).

Before going further we must clear up the confusion about the manner of the attachment of the spindle fibers to the chromosomes. Montgomery's position upon this matter is not clearly defined, but some idea of it may be gotten from the following statement: "All the chromosomes become so placed in the spindle that mantle fibers from one spindle pole are attached to one univalent element, and mantle fibers from the other spindle pole to the other univalent component of each bivalent chromosome." If Montgomery had examined his metaphase chromosomes more extensively and more carefully he would have found many lateral oblique views such as 8 and 11 of figure 32, or in plates XXI and XXII, such as chromosomes 11, 6 and 4 of series 2, or 11 of series 6, 10 of series 10, 7 of series 13, 12 of series 18, 6 and 4 of series 24, or 9 of series 25, all proving beyond a doubt, when carefully studied under the microscope, that the mantle fibers do not attach to univalent halves of bivalent chromosomes. Instead, each fiber is attached to the halves of the two univalent elements that make up the bivalent chromosome, *i. e.*, each fiber (and there are but two fibers running to each ordinary chromosome, one from each pole) carries off or leads off with it to its pole a half of one univalent element together with a half of the other univalent element that constitute the bivalent chromosome. Or

it might be stated in this way: Each fiber does not attach to one of the spermatogonial chromosomes that previously conjugated to form the bivalent chromosome but rather to a half of each member of the pair. The pair the members of which were united end to end becomes a pair split longitudinally, and the result of the splitting is two pairs instead of one pair. Each of the resulting halves or pairs may still be considered a conjugated pair, because it is made up of two distinct spermatogonial elements, as the original conjugated pair was. One of these halves goes to one pole and the other to the opposite pole. The behavior of the chromosomes in a first spermatocyte division, as far as the ordinary chromosomes are concerned, is much like that of those in a spermatogonial division. In both kinds of cells the chromosomes are paired. The difference is that in the spermatocyte the members of a pair during mitosis (as well as at other times) cling together by their proximal ends (sometimes by the distal ends), while in the spermatogonium the members of a pair remain separate. In both cases the division is longitudinal and always begins at the inner or proximal end. The division of the ordinary chromosomes in the first spermatocyte is therefore not a reduction or cross division, not a separation of the members of a spermatogonial pair, but a longitudinal, an equation division, by which each of the resulting daughter-cells receives a half of all the *ordinary* chromosome elements that were present in the mother-cell. The accessory, of course, which does not divide in this mitosis, is an exception and will be taken up later.

Lastly, mention must be made of the chromosomes which Montgomery describes as "irregular V forms" and which he designates by "K." He says that "Whereas ring-shaped chromosomes are frequent in the preceding late prophases they are only very exceptionally found in the equatorial plate, so that probably by the pull of the mantle fibers upon them these ring forms change into the form of the chromosomes lettered *K*." Montgomery has evidently seen no polar views of the first spermatocyte equatorial plate. Figures 30 and 33 of plate XIX and series 1-25 of plates XXI and XXII show without doubt the presence of these ring forms in the metaphase. His chromosome K is merely a lateral or an oblique-lateral view of a ring tetrad that has gone part way into mitosis, and

not an irregular V. If viewed from the pole it would easily be seen to be a ring. The ends or tags pulled out, and to which the spindle fibers are attached, are evidently what he describes as "ends of the univalent halves of the tetrad pulled past each other." In other words, he considers the ring chromosome a loop and these points where the fibers attach, these projections that stick out on opposite sides, the crossed ends of the loop gliding past each other. He believes that one univalent half of the bivalent ring is simply being pulled away from the other half, one spermatogonial member from the other. But I am sure that he is entirely mistaken in this. These tags or projections are the ends (*XX* of the figures) of the transverse axis of the cross (a cross here modified to a ring). He has not taken into account at all the prophase form of the ring (fig. 29), which shows beyond a doubt the origin of these tags or projections. There it may be seen that each projection is made up of part of one univalent half and of part of the other univalent half of the ring. The ring may be thought of as a split ring, and the split halves of it as being pulled apart or as starting to move apart in the region (*XX*) where the projections arise, one half going to one pole and the other half to the other pole. This is the explanation that the prophase form of the ring affords, and it would be absurd to argue that the metaphase rings are anything more or less than prophase rings that have become very much condensed. Some of the chromosomes, possibly the smaller ones, may divide transversely, but no evidence has been found to confirm this view. I feel quite sure, therefore, that chromosomes of the ring and cross type do not divide transversely but longitudinally in this first maturation mitosis.

The last and most important correction which I have to make is in regard to the history of the accessory or "heterochromosome." Montgomery describes it as a bivalent element, not univalent, as it has up to this time been described for the *Acrididæ* and for Orthoptera in general. His mistake is due, in part at least, to some large chromatin-like nucleolar structures that are present, at first as two bodies and later as one, in the resting period between the last spermatogonial and the first spermatocyte division. He finds the accessory in the spermatogonia appearing for the first time in the form of a single coiled spireme enclosed within a vesicle of its own, some-

what similar to what Sutton ('00) describes for *Brachystola*. *S. admirabilis* (figs. 7, 8 and 9) agrees with this, but we fail to find that "when the nuclear membrane has completely dissolved away this single loop" (spireme) "segments into two." In his figure 6 it does not seem to me that he has furnished conclusive evidence that his N_2 elements are two heterochromosomes. How can he say for sure that both are heterochromosomes? One may be, but it is a certainty that they both resemble very much some of the other chromosomes. Had he shown the full number of the complex here, the number which he claims for the species, and had proven beyond a doubt that the number was even, not odd, his guess might have had some weight, but he has not shown the whole number in this particular cell nor has he convinced us that the number in the spermatogonia is even. His N_2 pair looks very much like the No. 6's or No. 7's of *admirabilis*. Of course, he claims to find an even number in the metaphase of the spermatogonia, but his two drawings do not furnish sufficient evidence to justify us in accepting this point as proven, especially since it must be accepted in the face of all the other evidence in the family, which in every case happens to be to the contrary. Following out the reasoning, he concludes that each "first spermatocyte receives a half of each of the two heterochromosomes" as well as a half of all the others.

In the reconstitution of the nucleus he again finds that when the "chromosomes begin to elongate and loosen up, two of them do not undergo these changes but remain smooth and dense" (cf. his fig. 13). These he considers identical with his N_2 elements of the spermatogonia. The strange thing, however, is that in his figure 14 the two heterochromosomes should suddenly conjugate and there should appear immediately thereupon, seemingly in the place of one of them, the single nucleolar structure *N*. If these heterochromosomes are to conjugate he should have found previous to his figure 14 three bodies, two heterochromosomes and a nucleolus in each nucleus. According to his figures there were only two bodies at first, the heterochromosomes, and after the conjugation of these there were two bodies still. There seems to be something wrong here, for it is improbable that a nucleolus would appear so suddenly as his element N. It must have been present before. And in addition to this, if his heterochromosomes

conjugated he should have given some intermediate stages showing the two moving together. In some cases (his fig. 20) the N structure is almost as large as his bivalent heterochromosome, which leads us to suspect that probably his nucleolus was in reality what he mistook, part of the time, for one of his heterochromosomes, and that his heterochromosome is not a bivalent structure. In speaking of the bivalence of the latter, at this point, it might be asked why his heterochromosome in the vesicle stage of the prophase of the last spermatogonial division should at first be a single element, then segment and remain separate during the metaphase as two heterochromosomes, and then in the first part of the rest period thereafter between the spermatogonium and the spermatocyte should conjugate again. This, too, seems unreasonable and improbable. From here on, throughout the remainder of the growth period, he finds but two bodies present, the "bivalent heterochromosome" and the "irregular nucleolus."

My work upon *Syrbula admirabilis* gives rise to two views regarding his N_2 structures in his figure 13. The first is that one of the bodies is the accessory seen in end view and the other body, of course, the true nucleolus. But if these structures are exactly the same size, as is quite likely the case, a second and more probable explanation is that he has not seen the accessory at all in this cell but has shown the two nucleoli which we find so often present in *admirabilis* in the early part of the growth period after the last spermatogonial division, as shown in figure 10 of this paper. What adds support to the latter view is the presence of two similar bodies in his figure 1 of a resting spermatogonium. What we have seen in *admirabilis* (fig. 7) convinces me that these two nucleoli in the spermatogonium are not heterochromosomes, for that element may always be found in the reticular condition in a vesicle of its own applied close against the nuclear wall. That there were two of these nucleolar bodies very generally present in *acuticornis* is confirmed by Montgomery in his own words: "With great regularity there is found in each nucleus two or three larger, somewhat irregular, deep-staining bodies. Whether they are nucleoli or heterochromosomes could not be decided by the use of the iron-hæmatoxylin stain." By using Flemming's tricolor stain, and also by careful observation of all prophase stages, I have decided that the bodies in question

are not heterochromosomes, or chromosomes of any kind, but are nucleoli which for a time seem to act like chromatin bodies but which later are found to be plasmosomes or true nucleoli that, on account of their great density, continue to hold the safranin stain for some time. Now after the last spermatogonial division where do these nucleoli go? May it not be possible that they still persist for a while as in figure 10? It seems quite probable that the nucleoli (what Montgomery terms heterochromosomes) of his figure 13 are the same as those of my figure 10, and that his heterochromosome as it lies in the region of the periphery of the nucleus may have been overlooked, for after the last spermatogonial division it is often difficult to distinguish it from the ordinary chromosomes, since they all seem to be in a more or less semifluid and also semireticular condition, much like the accessory itself.

In Montgomery's figures following (15, 16, 17, 18, 19, 20) his accessory is shown in its characteristic position near the nuclear wall. He is probably correct in thinking that it shows longitudinal splitting but wrong in maintaining that it shows transverse constriction. In *admirabilis* it has shown at no time a transverse constriction, nor was the longitudinal splitting noticed until the anaphase of the first spermatocyte division. That, however, does not prove that the splitting may not be present in the growth period. The bent accessories of his figures 18, 20, 24, 26 and 30 are not evidence of the bivalency of this element, for it often bends or coils upon itself, as shown by my figures 23-28, and the bend may occur in any region, not in the middle alone, and seems to be due to the extreme length. During its spireme stage it passes through a variety of shapes. At first it is much convoluted. Then as it shortens and thickens it usually lies bent upon itself for a time, but finally it becomes an almost straight rod.

Montgomery's Y chromosome of figure 33, which was tardy in coming to the equator but which he claimed did so later on, although he gave us no assurance of it in his drawings, is in all probability the accessory chromosome, for it agrees with what we have found for *admirabilis*, where in every cell at this stage it may be seen starting off undivided ahead of its fellows to one of the poles. Montgomery was wrong, however, in supposing that it had not yet taken up its position in the equator. In fact, it has already been there, as the dividing of

the other chromosomes indicates, and is now on its way to the lower spindle pole. That this is the case is shown also by the spindle fibers, for they are evidently exerting an influence on the ordinary chromosomes, since the latter are in the act of dividing. The accessory, as his own drawing shows, is attached by these fibers to but one of the poles, and that fiber must evidently be pulling it toward its pole. This is a point in which *acuticornis* agrees entirely with *admirabilis* (figs. 34, 35, 36). But chromosome Y of his figures 32 and 34 is positively not the accessory, because that element, we have found, does not divide in the first maturation mitosis but passes over undivided (figs. 37, 38 and 39) to one of the daughter-cells or second spermatocytes. He was therefore wrong in identifying it with the Y of his figure 33. If he had examined the full number of chromosomes in these cells (his figs. 32 and 34) he would undoubtedly have found the accessory in its peculiar position starting off ahead of its fellows, as he found it in figure 33.

The heterochromosome of *Syrbula* is therefore not a bivalent structure, for it is paired at no time during its whole course. It does not divide in the first maturation mitosis but in the second. Montgomery quotes McClung as describing "for *Hippiscus* an accessory chromosome of the spermatocyte, said to divide in both maturation mitoses." This is a mistake. McClung gives no such description. As he was unable at the time to follow it farther or to distinguish it from the ordinary chromosomes after it had taken up its position in the metaphase of the first division he merely supposed that it must behave like the other chromosomes, and with that remark left it, expressing the intention of making it the subject of a subsequent paper. Since that time it has been found to behave as in other Orthoptera, dividing only in the second division.

And now Montgomery attempts to reconcile the "double heterochromosomes" of the Hemiptera with the single heterochromosome or accessory of the Orthoptera. His suggestion is as follows: "In the Orthoptera the heterochromosome is single in the spermatogonia; single therefore in the spermatocytes, it does not divide in the first maturation mitosis, but does in the second. Because it does not divide in the first mitosis it must be either univalent or else, already in the spermatogonia, be composed of two so firmly united that they can-

not be divided in the reduction mitosis." In reply to this the results obtained on *admirabilis* have shown beyond a doubt that the accessory is not paired in the spermatogonia. In addition to this it might be said that no workers upon the Orthoptera, except Montgomery himself, have ever found this element to be a bivalent structure, and more than this, it has been shown by Wilson ('05) that in the majority of the Hemiptera even, where Montgomery found most of his evidence for a double heterochromosome, the accessory (heterotropic chromosome) is unpaired, and Wilson believes that "it will be found to be so in all" Hemiptera. Montgomery's attempt, therefore, to bring these two classes into harmony, was first of all based upon inaccurate observations, and since that time has accordingly been rendered entirely unnecessary by more thorough researches.

His final summary is that "all chromosomes and heterochromosomes, be they paired or single in the spermatogonia, divide reductionally in the first maturation mitosis, whether the division consists in two univalent components separating from each other or a single component passing undivided into one of the second spermatocytes." As far as the Orthoptera are concerned it is true that in the case of the single component passing undivided into one of the daughter-cells there is a reduction, for only one-half of the second spermatocytes receive thereby this chromosome, but it is not true that all the other chromosomes in the complex divide reductionally in this mitosis, proof of which has been amply afforded by the behavior of the rings and crosses in *Syrbula admirabilis*, in *Hippiscus* (McClung, '00), and in the *Locustidæ* (McClung, '02).

INDIVIDUALITY AMONG CHROMOSOMES.

The most live problems to-day in the field of cytology are those which center around the belief that chromosomes are discrete individual elements, which in every nucleus are constant and definite morphological structures, occurring from generation to generation and bearing in themselves the power to transmit the characters of the species. Therefore everything that in any way adds to our knowledge of this subject, either new or in confirmation of what has already been learned, will be of interest. The chromosomes of *Syrbula admirabilis* are well adapted for a study of these questions on account of their favorable separation from each other in the metaphase figures,

their unusually large size, and especially on account of the great variation in size among the members of the complex. The tables which have been arranged in plates XXI and XXII were gotten up from such complexes as are represented by figures 30-33, 40, 41 and 1-6. In these tables the twelve chromosomes of a cell are strung out in a horizontal row or series. Each individual chromosome is given a position in its series according to its size, the largest, No. 12, coming first, No. 11 second, etc. The series are placed one below the other, so that like chromosomes will appear in the same column. In this way all the No. 12's throughout the series of cells will be found in the first column, the No. 11's in the next, and so on for all the chromosomes belonging to each specific size or rank. In the plates the first twenty-five series are from that many polar views of first spermatocyte metaphases and were taken from four different animals (A, B, C, D). In series 24 and 25, under D, the chromosomes seem much larger than in any of those preceding. This was due to the stain used, Flemming's tricolor, which has a tendency to swell the structures. The chromosomes of the other series were stained with iron-hæmatoxylin. In series 26-29 are shown the chromosomes of the two forms of second spermatocytes, those with the accessory and those without, and in 30 and 31 two series from spermatogonial metaphases (taken from figs. 2 and 6, plate XVIII).

In arranging the members of a series it was often difficult to determine the relative position of some of those nearest in size, because in some cases there was very little size variation while in others the true size was hidden on account of the position of the chromosome in the cell-plate. The latter was the case when ring-like forms were turned on edge or when those of a rod or kidney shape were viewed from the end. But although there may be doubt in regard to the position and size of those nearest each other in the series, such as Nos. 6 and 7 or 8 and 9, there is absolutely no danger of confusing those of such wide range as Nos. 12 and 6, or 10 and 5, or even of those as near as Nos. 10 and 7.

There are in a general way six columns (12, 11, 10, 9, 7, and 4) in which ring-like forms occur. The other columns contain chiefly straight or bent rods. In regard to the ring-like forms a word of explanation is here necessary. A ring, as has

been explained by others and once already in this paper, consists of two homologous spermatogonial chromosomes joined together by their ends, proximal end with proximal and distal with distal. The proximal ends are always united, but the distal ends may or may not be. Sometimes they are so firmly joined that the distal end or region of the ring cannot be told from the proximal except by the fact that the proximal portion always points towards or lies nearest to the center of the cell-plate. In these tables (plates XXI and XXII) the rings are always placed as nearly as possible in a position with the proximal portion uppermost. In the case of the kidney-shaped or bent-rod forms in columns 8, 6, 4 and 3, and any similar chromosomes that may occur in other columns, the proximal end or part (the convex side) of the chromosome is turned towards the left. To be logical this portion in these chromosomes should have been turned upwards, as in the ring forms, but less room was required the other way. In the case of the accessory the proximal end is again as far as possible placed uppermost. In series 26-31, from the spermatocytes and the spermatogonia, the proximal end, that to which the fibers are attached, is always placed uppermost.

In the formation of the rings quite often the distal ends are imperfectly or not at all united, but the polar or proximal ends are always united. It does not seem to be necessary that the distal ends shall always unite, but there is a tendency for them to do so, and this tendency is greater in certain individual chromosomes than in others. In general, the larger chromosomes seem to be more inclined to form rings than the smaller. Nos. 12 and 11, according to these cells, are always rings or ring-like forms. Some possible exceptions occur, principally in the second column (chromosome 11 in series 2, 8, 19, 22 and 23) where the distal ends are either imperfectly or not at all united. But nevertheless the distal ends of the pair bend around toward each other, showing that they have a tendency to unite and form a ring. In series 5 and 6 of column 10 two notable exceptions occur: that in series 5 is somewhat inclined to form a ring, but that in 6 has no inclination whatever to do so. In series 18 the distal ends of No. 10 seem to have glided past each other. In such as that in 15, 16, 20, 21 and 23 the distal ends have not moved past each other, but they evidently did not meet exactly on end, as is shown by the

drawings. Some chromosomes, such as 12 and 11 of series 2, or 10 of series 19, show by the length of their transverse axis that they have advanced farther in mitosis than many of their neighbors. The chromosomes in column 9 seem all to belong to the ring-like form. That in series 6 is not a ring now but it may have been before it became drawn out so far. This is a good example of a chromosome completely elongated in the transverse direction. The No. 8's are all very constantly kidney or bent-rod forms. There is very little difference in size between them and the No. 7's. Of the No. 7's, nineteen out of the twenty-five are rings. The others are usually of kidney form. That in series 20 is rod-shaped. The point at which the fibers attach is indicated by the *X*. In column 6 the chromosomes are all kidney-shaped with two (series 23, 25), possibly one, exceptions. The exceptions may be considered ring forms, but they may also be bent rods, for one of them (series 23) has the distal ends of the two halves of the ring not united at all, while the other (6 of 25) is so nearly the size of chromosome 4 of the same series, which is not a ring, that possibly I may have the two interchanged. In column 5 is the accessory. There is no trouble in finding the proper place for this element, since it may always be recognized in the cell by its form, and especially by its position in the cell-plate (figs. 30-36.) In size it seems to fit between the No. 4's and 6's. On account of its habit of starting off to the pole ahead of the other chromosomes it so happens that it nearly always appears either in cross-section or a very much foreshortened side view. Sometimes, but not often, it is seen in full lateral view in the metaphase plate. As to individuality there is no member of the complex that is more pronounced than the accessory. It is the only element that may be traced from the prophases of the spermatogonia through all the stages of the growth period and the division stages of the first and second spermatocytes up to the spermatids. It seems at times to be an element peculiar unto itself, and yet when viewed in the metaphases it behaves very much like the other chromosomes, even so much so that it is with difficulty distinguished from some of them (the 4's and 6's in first spermatocytes and 10's in spermatogonia). In all respects it is a chromosome, but one whose individuality as to form, size, and habits is very strongly marked. In column 4 about one-half the number are rings

and one-half are kidney-shaped. The small chromosomes (3's, 2's and 1's) are always rods. The largest of them may show a kidney shape. Sometimes in far advanced metaphases, as in series 1 and 2, the second smallest (No. 2) is divided.

A study of the chromosomes as they appear in these series furnishes very strong evidence that they are discrete individual elements. There are three means by which chromosomes may show their individuality—by size, by shape, and by function. Boveri ('02) proved for them an individuality of function, Sutton ('02) that of size, and Baumgartner ('04) that of shape or form. The series here arranged suggest nothing in regard to function, but they do point to an individuality of size and to a certain extent of form. Of the two latter characters size seems to be of most consequence. The form of a chromosome seems not to be essential, for it may vary to a certain extent, but the size remains the same. A very clear idea of this size relation may be obtained by observing the second spermatocyte series, 26-29, for in any one of these series all of the members except the accessory are of comparatively uniform diameter, and to get the size relation all we need to do is to compare their lengths. In the spermatogonial series (30, 31) exactly the same size relations may again be seen. This size relation is a constant. In the first spermatocytes every cell shows a series, or complex, of chromosomes, every member of which bears to its fellows the same relation in size as do those of any other cell. If any of the group in the cell are large they are all proportionately large; if small, they are all likewise small. The relative sizes remain the same in either case. Then, too, this size relation is the same from one generation of cells to the next as well as among different cells of the same generation. For the proof of this compare the series from the spermatogonia and second spermatocytes with those of the first spermatocytes.

In cells from each of these generations it has been observed that there are always two groups of chromosomes in the complex that may easily be recognized, the three extremely large ones (12, 11, 10) and the three extremely small (3, 2, 1). They may be seen in the prophase stages as well as in the metaphase. The grouping seems to be characteristic of the *Acrididæ*, for it is found in all three of the subfamilies. Sutton ('02) described it for *Brachystola*, one of the *Œdipodinæ*,

Nowlin ('08, just being published) for *Melanoplus*, one of the *Acridiinæ*, and Montgomery ('05) *Syrbula acuticornis*, one of the *Truxalinæ*. Whether there is anything of particular significance in the fact or not will of course appear later on. The presence, however, of this grouping in every cell is again evidence of the individuality of the chromosomes, for it is a certainty that the members of these two groups are entirely distinct and different individuals. There is no danger of ever confusing any such large chromosomes as Nos. 12, 11 or 10 with any so small as Nos. 3, 2 or 1. The same might be said of any of the intermediate members of the series, those which approach each other more nearly in size, were we able to distinguish between them by their sizes. But the proof afforded by the extreme members of the complex is enough to establish individuality for all.

Shape or form among chromosomes, as mentioned above, does not seem to be a matter of first importance but is dependent in a measure upon size. It is true that some chromosomes, as Nos. 12 and 11 or 9, were found to be always rings throughout the twenty-five cells that were studied, but again No. 10 was found to have two out of the twenty-five that were not rings, and possibly if we had searched far enough the 12's, 11's and 9's would have shown similar variations. Yet the two No. 10's that did not form rings were in all probability as truly No. 10 chromosomes as any other No. 10's in the column, for No. 10 in series 5 or 6 bears the same size relation to its fellows in the series as do any of the ring-form No. 10's to their fellows. It is not essential that No. 10 be a ring, but it is essential that the limbs of 10 be long and that it contain the same amount and the same kind of material that all other No. 10 chromosomes contain. The fact that the limbs of this chromosome are long and slender makes it more possible for it to form a ring, since the limbs have a better chance to bend around toward each other. This possibly might in a general way account for the fact that more rings are found among large chromosomes than among small. The latter, however, is not always true, for chromosome No. 4, which is very small, may often be a ring, while No. 8, a much larger chromosome, is never a ring. Possibly the thickness and corresponding shortness of the limbs of the No. 8's may be the reason why they never form rings. Nos. 7 and 4

seem to be indifferent as to whether rings or kidney shapes are formed, but their limbs are usually slender and show that they may bend around to each other easily. The extremely small chromosomes, Nos. 1, 2 and 3, of course cannot form rings, on account of their shortness. Assuming that the diameter of the rods or univalent arms forming the chromosome is approximately equal for most of the chromosomes, the large chromosomes would then have a tendency to form rings because their limbs are long; the small one to form rods, and especially straight rods, because their limbs are short; and those that come between to form bent rods, V's and rings indifferently because their limbs are either too short always to insure rings or too long always to form rods. The question then as to whether a chromosome shall be a ring or not may be considered as depending in a general way upon the relation existing between the length of its limbs or arms and their diameter. Assuming, as we did, that this diameter tends to remain a constant, the chief determining condition would then be size, and we know the size relation in a chromosome is a constant, therefore the form which is dependent upon size would tend to be a constant. But it is not essential that these chromosomes shall always form rings or not, for the truth of the matter is that they are not always constant in this respect. Undoubtedly other agencies enter in to modify this secondary character, such as condition of the cytoplasm, position of the cell in the cyst, the degree to which the gliding of the chromatids had advanced in the tetrad before the condensation process of the metaphase had overtaken it. In respect to the cross form it may here be said that the fact that a chromosome appears as such is of no special importance in individuality, for, as has been already shown in this paper, all the ordinary chromosomes pass through this condition. It too may be considered of secondary importance. Many of these agencies thus working together no doubt prevent the chromosomes from doing exactly as they would otherwise do; and if such be the case it would only be that much more proof that the form of a chromosome is not a first essential, not an entirely reliable character upon which to judge individuality. These external conditions, however, do not alter the size relations of the chromosomes. That remains a constant under all circumstances. It seems fair to conclude, therefore, that form, though it ought

to receive due consideration, is not to be held as a first essential in the determination of individuality in the chromosomes but rather as a secondary character dependent to a large extent upon size.

SUMMARY.

1. There are twenty-three chromosomes in the spermatogonia. They may be arranged in a graduated series of eleven pairs plus one odd unpaired member, which is most likely the accessory. In this series there may readly be recognized three extremely large pairs and three extremely small pairs. The members of the pairs do not always lie together in the equatorial plate.

2. The accessory chromosome is seen for the first time in the prophase of the spermatogonia, where it may be recognized by the peculiar vesicle within which it lies, located at the periphery of the nucleus. It is at this time reticular in structure, like the other chromosomes. After the last spermatogonial division it remains condensed, while the ordinary chromosomes become reticular and diffuse. As usual in *Acrididæ* it lies in close contact with the nuclear wall, and it continues to maintain this peripheral position even in the spindles of the two maturation divisions that follow. In the growth period it passes from the telophase condition of the last spermatogonial division to a lump condition. Out of this lump is evolved later a long, slender, much-coiled spireme. This spireme continues to shorten and thicken, and the chromosome finally enters the metaphase as a short, thick, almost straight rod. During all this time this chromosome has shown no signs of being a paired or bivalent structure. In the prophase of the spermatogonia there was no spireme segmented into two parts. In the spermatogonial metaphase it was not paired, for the spermatogonial number of chromosomes was odd, not even. In the telophase of the last spermatogonial division, and in the resting and growth period following, it was not paired, for the second dense chromatin-like body present there was found to be a nucleolus, not a heterochromosome. In the latter part of the growth period and in the prophase of the first spermatocyte, when the chromosome had assumed the spireme condition, no constriction or bending at any particular place (the middle) was met to indicate that the element had already been paired before leaving the spermatogonia. On the con-

trary, it was found to be, under all conditions and at all times, a univalent chromosome.

3. In the prophases of the spermatogonia two deeply staining nucleoli are usually present. In the telophase of the last division and in the early part of the growth period following they are still present, staining red with safranin, like the accessory. In the middle and later growth period there is but one large nucleolus present, almost as large as the accessory. It fades out and disappears as the chromosomes enter the late prophase of the first spermatocyte and begin to condense.

4. There are twelve chromosomes in the first spermatocyte. No exceptions to this were found in a series of fifty or more cells that were examined, belonging to at least a dozen different animals. The chromosomes consist of rings, semiclosed rings, crosses, bent rods and straight rods. All of these forms may be considered as modifications of a single type, that of a rod with one longitudinal and one cross division. The cross division locates the point at which the spermatogonial pair conjugated by their proximal ends. This rod has the ability to change its long axis from a longitudinal to a transverse direction. All chromosomes of the first spermatocyte, except the accessory, pass through this process of change of axis. The cross form represents merely a transition stage in the process. Rings are merely spermatogonial pairs that have conjugated at both proximal and distal ends. Semiclosed rings, kidney shapes, bent rods and straight rods are those that have conjugated by the proximal end only. All the ordinary chromosomes divide in the first division. They divide longitudinally (equationally) not reductionally. The accessory does not divide but passes over complete to one of the resulting daughter-cells.

5. One half of the second spermatocytes therefore contains eleven chromosomes and the other half eleven plus the accessory. These dyads here correspond to pairs of homologous spermatogonial chromosomes. They are divided crosswise or reductionally. It is here that the maternal and paternal elements are separated from each other. The accessory divides longitudinally here like it did in the spermatogonia. One half the spermatids receive eleven chromatids and the other half twelve. This of course insures a dimorphism of the protozoa.

6. The chromosomes show individuality of size and, to a

certain extent, of form, but form is more or less dependent upon size. Size is a constant relation among the chromosomes, therefore form, which is dependent upon size, would have a tendency to be a constant. But it is not always a constant, *i. e.*, a chromosome which is usually a ring is not always a ring, although it tends to be. This is probably due to external conditions. Since this variation is encountered, form cannot be essential; hence not an entirely reliable character upon which to base individuality.

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ORGANIZATION OF THE CHROMOSOMES IN PHRYNOTETTIX MAGNUS.

BY EDITH PINNEY.

(Contribution from the Zoölogical Laboratory, No. 181.)

Plates XXIII, XXIV.

CYTOLOGICAL investigations in this laboratory on the spermatogenesis of various *Acrididæ* have resulted in discoveries of primary importance concerning the precision in the organization of the *Acrididæan* chromosomes. McClung, in a comparative study of "The Chromosome Complex of Orthopteran Spermatocytes,"* finds that a "definite series of chromosomes" occurs in all the members of the family, and that the modifications in size, form and association of these elements accompany variations in somatic characters that account for the division of families into genera and species. Striking examples of the constancy of such modifications were found in the multiple chromosomes of *Hesperotettix* and *Mermiria,* which he describes. In establishing the individuality of the chromosomes different workers have found these elements exhibiting constant characteristics of size, form and function.

In my brief study of the male germ-cells of *Phrynotettix magnus* I have found further convincing evidence of a precise and definite order governing the cell processes exhibited in the internal organization of the chromosomes. The work was done under the direction of Doctor McClung. The investigations of McClung on the "Spermatocyte Divisions of the *Acrididæ*"† and Sutton on the "Spermatogonial Divisions of *Brachy-*

* Biological Bulletin, vol. 9, No. 5, 1905.

† Kansas University Quarterly, vol. 9, No. 1, 1900.

stola magna"* make a detailed account of the manner of these divisions in this species unnecessary, since in my material the divisions display the typical order of the *Acrididæ*.

SPERMATOGONIA.

A polar view of the spermatogonial chromosomes of *Phrynotettix magnus* shows twenty-three chromosomes appearing as longitudinally split rods of varying lengths (fig. 1). The accessory chromosome (x) can be distinguished from the others by its rough contour and the more marked hyaline area surrounding it. In the succeeding anaphase, division is accomplished by a separation of the halves of the chromosomes. Separation proceeds from the proximal to the distal end and results in the proximal ends reaching the poles first. The same peculiarities that distinguished the accessory in the metaphase are also observed in this stage (fig. 2 x). During the anaphase the cell elongates in the direction of the spindle axis. The chromosomes are drawn close to the opposite ends of the elongating cell and, on account of their number and relative thickness, lie approximately parallel to each other (fig. 3). The spindle between the two groups of chromosomes which are to form the nuclei of new cells persists between the daughter-cells and fades away near the groups of nuclear elements. The subsequent characteristic changes through which the spindle remains pass form an excellent criterion in determining the sequence of the various changes which are observed in the cell. As the division wall is formed the spindle is slowly contracted. What Sutton describes as a tendency of the daughter-cells "to roll upon one another" is plainly seen from figure 4 to be a rolling of the nucleus, which forces the spindle fibers to one side of the cell. The same figure shows this peculiar movement of the nucleus to be accompanied by a disintegration of the chromosomes, which, together with the persistence of the spindle fibers, may bear a causal relation to the former phenomenon.

As the separation of chromatin granules begins the chromosomes move apart, retaining, however, their parallel arrangement, and each chromosome becomes surrounded by a delicate membrane forming the chromosomal vesicle. The dissociation of chromomeres in the telophase results in the diffusion of the chromatin within the vesicles, which, so far as I have

* Kansas University Quarterly, vol. 9, No. 2, 1900.

been able to ascertain, remain intact until an early prophase. In these stages also the accessory chromosome is readily recognized by its position, size and apparently advanced state of diffusion, which is consistent with the earlier appearance of tardy condensation observed in figures 1 and 2. The diffusion of chromatin within the accessory discloses to observation a small, black, spherical granule lying close to the vesicular membrane at its proximal end (stain, Heidenhain's iron-hæmatoxylin). This granule is always seen in the accessory in this stage and always at the polar end. The ordinary chromosomes in figure 4 do not show a similar element, owing to their slight degree of internal dissociation, but in the later stages, figures 6, 7, 9 and 10, its presence is clearly demonstrated.

The slight shifting of position of the chromosomes, due to the diffusion of the chromatin and the enlargement of the chromosomal vesicles, presents a difficulty when it is attempted to determine the location of the granules. Sections of cells may be cut in all conceivable planes and many misleading figures obtained. The sections in which the least complication occurs, and the ones best fitted for study, are those in which the entire accessory is visible in longisection lying at one side of the nucleus. (See fig. 6.) Here there can be no doubt as to which are the polar ends of the chromosomes, and their limits can be ascertained, showing that the polar ends of all of the chromosomes do not lie in the same plane but that the deeply staining round granules which mark their polar ends lie near the same side of the nucleus. It is also noteworthy that these black bodies occur only at the polar ends. Other chromatin masses which are observed occasionally at other points within a chromosome are indistinct in outline, irregular in shape, and cannot be shown to be constant, so are not to be confused with the polar granules.

In cross-section of these diffused stages we obtain such figures as 7, in which we are looking down on the proximal ends of the chromosomes, and in figure 8, which is a section through the central or distal portion of the chromosomal group. Figure 8 shows the stage midway between two succeeding metaphases in which the dissociation of chromomeres is at its maximum, and is present in the same degree in all of the chromosomes. Here too the polar granules prove constant in occurrence, staining qualities and position.

The two stages immediately following the one shown in figure 9 must be studied side by side to interpret correctly the nature of the changes which take place. In figure 10 the change seems to be merely a closer aggregation of chromatin particles in which a transverse striation is noticeable. Comparing this with the following condition, seen in figure 11, we can plainly see that the beginning of the prophase involves the organization of the chromatin into a much convoluted thread.*

The manner in which the condensed homogeneous elements viewed in figure 1 are formed from the long, loosely organized spirals of figure 13 is shown by a comparison of figures 10 to 15. With the beginning of the prophase, figure 10, the contiguous walls of certain vesicles disappear, resulting in a formation of a few (actual number uncertain) large non-intercommunicating vesicles each containing a number of rods showing a longitudinal split. The accessory in figure 14 does not exhibit this division. The entire disappearance of the chromosomal vesicles and the arrangement of the chromosomes in the equatorial plate, figure 1, marks the completion of the series of changes comprising one spermatogonial division.

In the telophases of the last spermatogonial division the changes are somewhat different from those just described. The chromosomal vesicles, with the exception of that surrounding the accessory chromosome, disappear with the diffusion of the chromatin and the nucleus becomes spherical in shape. The accessory seems to vary in the amount of diffusion that it undergoes but is usually observed as a slender black-staining rod closely appressed to the nuclear wall.

FIRST SPERMATOCYTE.

The diffused chromatin of the last spermatogonial telophase is found in the early spermatocyte prophase to be reorganized into a number of filiform segments which show a characteristic arrangement. The accessory chromosome, a shapeless mass of homogeneous chromatin, lies at one side of the cell (fig. 16 *x*). Near it, and next to the nuclear wall, is a group of bodies resembling the accessory in all but size, being much smaller. From these the chromatic threads extend outward, each segment apparently forming a loop the ends of which have their termination in the smaller chromatin bodies. A. and K. E.

* The author was unacquainted with Bonnevie's work, "Chromosomen Studien I, Archiv für Zellforschung," Bd. 1, Heft 2-3, which appeared after this was written, and which describes similar changes.—C. E. M.

Schreiner, in their studies of *Spinax niger* and *Myxine glutinosa*, have described a looped arrangement of the thread during the conjugation period similar to figures 16 and 17. Here conjugation takes place by the lengthwise union of entire threads, each chromomere of one uniting with a homologous chromatin unit of the other, thus forming a thicker chromatin thread with a longitudinal division. No such union of threads as they describe has been observed in my material. The division in the thread precedes that in the polar granule, and often we find several polar granules united with the radiating threads showing a longitudinal split (figs. 19, 20 *a*). Here again we have a resemblance to one of the figures of the above authors, in which they find the chromatin threads radiating from a chromatic body which they call the "Knotenkörper." Figure 19 shows the accessory chromosome with no threads attached.

By a subsequent contraction and longitudinal splitting of these threads in figure 16, tetrads like those shown in figure 18 are formed. The interesting and peculiar feature of these formations are the condensed bulbous thickenings marking the synaptic end of each chromatid. These changes have taken place within the nuclear membrane. The accessory has assumed a regular form and still maintains its lateral position. The lesser bodies, grouped as represented in figures 16 and 17, are missing unless we identify them with the condensed thickenings on the ends of the chromatids. As the chromatids coalesce the longitudinal divisions of the thread and its homogeneous ends are obliterated, and we find many figures resembling figure 18*f*. Oftentimes these peculiar enlargements occur at each end of a chromatid. This is confusing and, in the light of my limited observations, unaccountable. Figures 21 to 27 show the usual succession of changes in the first spermatocyte division. There are twelve chromosomes in the metaphase. Figures 22 and 23 show the constancy of form which prevails within the species. There are always two large rings, six smaller rings, two very short rods, and one longer rod. The accessory, homogeneous throughout the prophases, becomes rough in outline during the brief moment of its journey to the pole, but regains its smooth contour in the telophase of the first spermatocyte (fig. 28). A slightly later telophase shows the accessory less condensed but apparently

not increased in size. A like change in the ordinary dyads now shows granules in their synaptic ends staining similarly to those previously noted in the spermatogonial chromosomes. (See fig. 29.)

SECOND SPERMATOCYTE.

The ordinary dyads in a prophase of the second spermatocyte resemble those in figure 28. The condition of the accessory was not noted. Division proceeds in the usual manner, resulting in the separation of single chromatids (figs. 30-32). Figure 33 shows a cell formed by this latter division. Diffusion of the chromatids has taken place within the nucleus. Persisting bodies of chromatin are noted distributed irregularly through the less concentrated nuclear substance. A round, deeply staining mass of spindle fibers is observed adjoining the nucleus (fig. 33 *a*). After the stage represented in figure 33 we obtain figure 34, a late stage in the developing spermatid. All traces of material staining like condensed chromatin have disappeared with the exception of the middle piece (fig. 34 *a*). It is uncertain whether this body lies within or without the membrane *b*.

CONCLUSIONS.

In conclusion, I wish briefly to summarize and correlate the history of the unusual chromosomal elements noted in the four generations of germ-cells just described. I have already referred to those occurring in the spermatogonial chromosomes as the polar granules. There their prominence and constancy claim for them recognition as important elements in the organization of the individual chromosomes. By a consideration and comparison of figures 4, 6 and 9 it is plain that the position of these granules coincides with the proximal ends of the chromosomes, and evidently, from figure 6—which shows that the granules occupy that point of the chromosome which is nearest the pole—mark the point of attachment of the spindle fiber. If now we can prove that these granules maintain the same position with respect to the remaining portion of the chromosomal substance throughout its life-history, and also that every such granule is the direct descendant of a preceding granule exactly like it in form and position, we may, I think, safely conclude that every chromosome is definitely and unchangeably polarized and that the point of spindle fiber at-

tachment is constant. In view of the lateral position of the polar granules in the telophases of the spermatogonia and their proximity to the accessory chromosome, I am convinced that in the small bodies of condensed chromatin in figures 16 and 17, showing early spermatocyte prophases, we have the direct product of two conjugating polar granules. Each polar granule contains material from each chromatid, and consequently, in the tetrads of the first spermatocyte, when the division between chromatids is apparent, we have from the union of two polar granules four bulbous thickenings at the synaptic ends of the tetrad, which indicate also the location of the spindle fiber attachment. Through the processes which follow, these centers of condensation prove permanent elements, reappearing in the dyads of the ensuing telophase (fig. 29). From these observations it appears that the polar granules are permanent bodies, not undergoing marked physical change during the processes of the cell division. This permanency of position, in the case of the polar granule, seems to indicate the existence of a force which governs the relative position of the constituent elements of the chromosome through its various changes. Such a function may be ascribed to the linin thread which undoubtedly forms an important part of every chromosomal entity.

The occurrence of condensations at the distal ends of the chromatids occasionally observed in the spermatocyte tetrads cannot be explained by the preëxistence of similar condensations in the spermatogonial chromosomes, for such are lacking there.

It would be interesting as well as instructive if we could determine definitely the function of these polar granules. Unquestionably they are in some way concerned with the definite polarization of the complex element to which they belong, and their relations both to the spindle fiber and to synapsis is significant. In consideration of this question Doctor McClung has suggested a comparison of the polar granule in the spermatogonial chromosomes with the body from which the axial filament of the spermatid grows. The analogy consists in the fact that in both cases we have a small, definitely formed mass of homogeneous chromatin located at one end of an elongated membranous vesicle and marking the attachment of a movable filament, but we are unable to judge the meaning of these

similarities, since we have no evidence as to the fate of the polar granules in the developing spermatid. I am inclined to believe that the bodies observed in figure 33 are the persisting polar granules, but whether these undergo further dissolution or unite to form the middle piece of the mature spermatid must be left for decision by future investigations.

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THE RELATIONSHIP OF THE TURTLES AND PLESIOSAURS.

BY ROY L. MOODIE.

(Contribution from the Zoölogical Laboratory, No. 182.)

Two text figures.

THE question of the relationship of the turtles and plesiosaurs has interested zoölogists since the time of Buckland, when the nature of the latter animals was first clearly understood. At about this time, too, the first comparisons were made between them. Conybeare compared the plesiosaur to a "turtle stripped of its shell." Mantell remarked that the structure of the plesiosaurs was such as to "justify the graphic simile of an eloquent professor, that the plesiosaurus might be compared to a serpent threaded through the shell of a turtle."[1] Again, Mantell tells us that the "plesiosaurus" combines the characters of several orders of reptiles and has "paddles like the turtle." Ever since the utterance of these statements an affinity between the two groups has been claimed, and this has been based on various grounds. It is the purpose of this essay to review the bases for the relationship and to discover, if possible, the exact conditions in regard to the so-called affinity.

Parker stated that on account of the greater number of segments in the neck and tail of certain turtle embryos that there was a suggestion of relationship between the turtles and plesiosaurs. He strengthened this suggestion by the statement that some of the Cretaceous Chelonia possessed teeth. Seeley called attention to the similarity in the method of ossification of the limb bones in turtles and plesiosaurs, and referred to

1. Mantell, 1851, Petrifactions, London, p. 341.

"conical epiphyses" which penetrate into a cylindrical sheath "so as to meet, or nearly meet, in the center." The turtles and plesiosaurs both have a very peculiar scapula. In both groups it is fundamentally biradiate, and it has been claimed that this condition of the scapula is due to the fusion of the procoracoid to the true scapula in both groups and the homologous mode of formation of this element was made the basis for relationship. Further relationship has been claimed on the fact that the broad character of the pectoral and pelvic girdles of the plesiosaurs resembles to some extent the plastron of the turtles, and there has been some attempt to correlate the elements in the two groups. There is, also, an undoubted similarity in the manner of life of the two groups, and this has been a claim to affinity.

The question of the relationship of the turtles and plesiosaurs has been discussed by various authors, notably Seeley, Hulke, Baur and Williston. An impetus toward the final conclusion of the matter has been given by the recent studies of Williston on the skull of *Brachauchenius*, and by the author's studies on reptilian epiphyses.[2]

The first basis of relationship to be discussed is that of the number of segments in the neck and tail of turtle embryos, first brought forward by Parker.[3] He says (p. 50): "One of the most remarkable things in the embryo (of the green turtle) is the large number of somatomes, in the neck especially, and also in the tail, as compared with what is seen in the intercalary bony segments (vertebræ) of the adult; thus the embryo suggests an ancestry having a longer neck and tail than existing forms. As some of the Cretaceous Chelonia certainly possessed teeth, . . . it is evident that the modern Chelonia are forms that have become separated from their near reptilian relations by specialization. A long-necked ancestry with a fully developed carapace and many bones of the plastron arranged triserially would bring us near the plesiosaurs."

Parker has figured (plate I, fig. 3) an embryo of *Chelone viridis* Schneid., with fifteen somites in the neck and thirty-six in the remainder of the body. The somites as he has figured them in the neck are very unnaturally crowded and packed, and indeed Parker himself noticed this fact. He says that in the development there are seven "somatomes" lost from

2. Moodie, 1908, Amer. Jour. Anat., vol. VII, p. 443.

3. Parker, 1880, Zoölogy Challenger Expedition, vol. I, pt. V.

the neck. The body portions remain as they are, and three are lost from the tail. The manner of development of the tail is not of importance in this connection, so that will not be discussed here. So far as I can learn, Parker's observations as to the large number of somites in the neck have never been confirmed. They certainly are not confirmed by the figures given by Rathke and Agassiz. Nor am I able to find any indication of supernumerary segments in the twoscore or more embryos I have examined, both in sections and whole. I am at a loss to explain Parker's observations, unless it be that his material was pathological. He had only a few specimens at most, and he fails to state how many show this remarkable character. I have carefully examined embryos of several genera of turtles and find nothing unusual in any of them. Before the cartilage is laid down for the vertebræ there are, of course, the somites, but I have never detected any unusual number nor have I seen more than eight cartilages for the vertebræ of the neck. So far, then, as the evidence goes, Parker's results are at variance with the results obtained by others. It can at least be said that the condition described by him for the embryo of *Chelone viridis* Schneid. does not apply to the other turtle embryos examined, and it is to be greatly doubted if there are ever more than the usual number of segments in the normal embryo. So far as I can learn there are no evidences of a reduction, ontogenetically, of the number of segments in the neck of any form, although such has been claimed for some of the birds. It is a matter which is easily conceivable that the loss or addition of vertebræ in the column may take place, and Baur has cited a few such cases. This is, however, by intercalation, and just what its significance is I do not know. Such an instance has never, I believe, been recorded for the turtles, and there is no evidence that the Chelonia ever had more than eight cervicals, while the plesiosaurs had from thirteen to seventy-six.

Teeth have never been discovered in the turtles. Marsh, it is true, described[4] the anterior portion of a peculiar mandible which he suggested might belong to the Chelonia. He says: "So far as now known, they appear to be nearest allied to the Chelonia, although turtles without teeth occur in the same strata with them." Hay says the fossil is problematical, and locates the form, *Macelognathus vagans* Marsh, among the

4. Marsh, 1884, Amer. Jour. Sci., p. 341.

Dinosauria. Teeth buds have been discovered in the embryos of *Trionyx* and *Chelone* by Röse[5], but the presence or absence of teeth in the turtles, unless of a particular type, would be of no classificatory value. Teeth have been aborted for so long in the Chelonia that their form cannot be determined from the embryonic vestiges.

The "conical epiphyses" which have been referred to as present in turtles and plesiosaurs are not epiphyses at all, but are endochondral cones such as are found in all the groups of the Sauropsida, and they are represented by cartilaginous cones in the Amphibia. The term "epiphyses" was first applied to these structures by Seeley,[6] who used the term inadvertently, I believe, and did not at all intend to convey the idea that there were present in the turtles and plesiosaurs "characteristically mammalian elements."[7] That these structures are not epiphyses is well shown by the condition found in

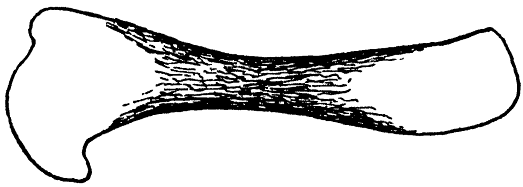

FIG. 1.

the limb bones of certain lizards. In the humerus of the Galapagos lizard, *Amblyrhynchus*, for example, there are present three sets of structures. These are the peri- and endochondral tissues and the terminal bony epiphyses, which differ from the mammalian epiphyses in that they are in part formed of calcified cartilage. Epiphyses are always situated at the ends of bones and never penetrate the shaft to any extent. The so-called epiphyses in turtles and plesiosaurs penetrate the cylindrical shaft and almost meet in the center. These structures persist throughout the life of the individual, of the plesiosaurs at least, but in the turtles they are not so persistent. In some forms of the Chelonia the endochondral cones are replaced by cancellated bone. The manner of development of the cones and perichondral cylinder is well shown in figure 1. The fibers of bone are densest near the middle of the shaft and splay out near the ends of the bone. The endochondral

5. Röse, Carl, 1892, Anat. Anz., Bd. VII, p. 748.

6. Seeley, 1887, Phil. Trans., p. 191.

7. Osborn, 1903, Mem. Am. Mus. Nat. Hist., vol. I, pt. VIII, p. 465.

cone occurs within the perichondrium. Neither turtles nor plesiosaurs have epiphyses, and there is, hence, no basis for relationship between the two groups so far as these structures are concerned.

The relations and shape of the pectoral girdle have also been used as a basis for relationship of the groups under discussion. It has been claimed that the biradiate character of the scapula in the two groups is due to the fusion of the procoracoid with the true scapula. The fact that the fusion was alike in the two groups is, therefore, taken as a basis of relationship. In neither group, however, has this fusion taken place. I have recently studied the development of the skeleton in the Chelonia and hope to present a full discussion elsewhere.

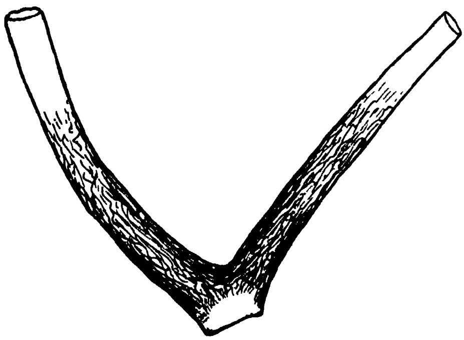

FIG. 2.

The question which interests us here is the condition of the scapula in the early chelonian embryos. In turtles, as has been stated, the scapula is a biradiate element. If it were a composite element there should appear, in the early embryonic stages, at or near the center of the shaft of each prong, a center of ossification, or at least a center of calcification in the very early stages. Specimens have been cleared by the Schultze method, recently set forth by Mall, Hill and myself, and in these specimens it has been possible to ascertain the exact condition of affairs.

The method of ossification in the embryos of reptiles is very peculiar. The bony matter is laid down in long wavy threads, which extend in a cylindrical shaft around the central part of the bone, being densest near the middle of the shaft. The bony fibers in the scapula of *Trionyx*, as shown in figure 2, do not depart from this plan of formation.

The fibers are not found to be densest near the center of the

shaft of each prong, but at the base of the V, where we would expect it if the scapula were a single element. The threads of bony matter are seen running in both directions and along the sides of each prong from the base of the V where they have their origin. At the base of the V the fibers are most compact, and here is the center of ossification for the scapula. In order to be sure that the single condition was found in early embryonic life before ossification sets in, sections have been made which show that there is no separation in the early stages of the element, and that both prongs originate synchronously. The fibers do not occur in the glenoid fossa but are present on the inner side of the V. The glenoid cavity, as stated by Rathke, remains cartilaginous.

Rathke has obtained practically the same result in some forms, and in others he secured results which would seem to be contradictory. His final conclusion is that there are two elements in the scapula, although he studied forms which showed clearly but one ossific center. Hulke[8] has rather misinterpreted Rathke and converts the embryologist's language into meaning that he had discovered two centers of ossification for this bone. As a matter of fact, the fibers of bone when laid down are very difficult to see in the early stages. Especially would this be true in dissected specimens, and it is no wonder that Rathke thought there were two in some and one in others. That he did discover forms in which there was but a single center is evident from the following: "In jedem Stücke aber geschiet dies[9] nicht, . . . an zwei Stellen, sondern nur an einer, und zwar in der Nähe der Grube für das Schultergelenk . . ." Parker, working some sixteen years later, came to the latter conclusion in regard to the scapula, for he says, four years after his investigations: "This front fork forms with the scapula a gentle arc; it is of the same thickness, nearly the same length and has no separate osseous center, the two bars being hardened by one ectosteal sheath."[10] Baur has called the anterior ray of the scapula the "proscapula," but Andrews suggests that a better term would be the proscapular process, since the former term implies the existence of a separate element.

There is no great similarity in the fundamental structure

8. Hulke, 1893, Proc. Roy. Soc. Lond., p. 249.

9. Rathke, 1848, Ent. Schild., p. 139.

10. Parker, 1868, Structure of Shoulder Girdle, Ray Society, p. 141.

of the scapula of turtles and plesiosaurs. In the turtles the element is fundamentally biradiate, but in the plesiosaurs it is merely a curved plate-like element, which hardly has the appearance of the V, so characteristic of the Chelonia. The radiate character of the scapula of plesiosaurs is ontogenetic, as Andrews has shown.[11] The scapula of turtles early assumes the V shape, and this is evident in very young embryos. The radiate character of the plesiosaurian scapula is not attained until the animal becomes adult. The three rays thus formed by the growth of the outer process was used by Hulke for correlation with the shoulder girdle of the turtles. But this correlation falls to the ground when we learn that the third ray of the chelonian girdle corresponds morphologically with the broad pectoral element, the coracoid, of the plesiosaurs. It has been shown above that the turtle scapula is a single element, and the singleness of the plesiosaurian scapula is vouched for by Seeley, Baur and Williston. "As to the structure of the scapula, all students of the plesiosaurs are now agreed that the procoracoid does not unite with the scapula, . . ."[12] The scapulæ of turtles and plesiosaurs are analogous in their form but they differ greatly and fundamentally in the two groups by the formation of the third ray in plesiosaurs. Seeley[13] has agreed with the results above given. He likewise was of the opinion that Hulke had misinterpreted Rathke. Hulke's greatest error lay in giving a portion only of Rathke's results and taking that portion as positive evidence for two ossific centers. Seeley objects strongly to the idea that there is any procoracoid in the scapula of the plesiosaurs and disclaims any relationship between turtles and plesiosaurs on the basis of the structure of the shoulder girdle.

The whole discussion of the relationship of turtles and plesiosaurs, as based on the elements of the pectoral girdle and the "epiphyses," has revolved around structures which are not present in either group. Neither group has epiphyses, and in neither group is the scapula composite. There is thus no basis for an affinity on the ground of these structures.

The claim that the broad pectoral and pelvic elements of the plesiosaurs are homologous to the plastron of turtles can hardly be valid. The broad character of the girdles in the

11. Andrews, 1895, Ann. and Mag. Nat. Hist., ser. 6, vol. XV.

12. Williston, 1907, Proc. U. S. Nat. Mus., vol. 32, p. 488.

13. Seeley, 1893, Proc. Roy. Soc. Lond., p. 161.

plesiosaurs is a secondary character, and whatever resemblance there may be is merely a parallel one. The coracoid of the plesiosaurs, which forms the broadest element in the girdle, finds its homologue in the coracoid of the turtles which is *within* the plastron and forms no part of it. The same may be said of all of the elements of the pelvic girdle. The elements which are supposed to form the plastron are the ventral ribs, the interclavicle and clavicles. All of these structures are present in the plesiosaurs, but they are also found in the ichthyosaurs and nothosaurs.

Williston has recently shown[14] that there can be no grounds for relationship between the two groups on the structure of the skull, and disclaims any relationship on the structure of the vertebræ and paddles. The skull of the turtle is as far removed in its structure from that of a plesiosaur as it well can be. In the turtles the skull is completely roofed over, and there is not a vestige of a temporal bar or vacuity. It is known as the stegocrotaphous type of cranium. The plesiosaurs, on the other hand, have the mammalian type of cranium, and possess but a single bar and a single enclosed vacuity. This type of skull Williston calls the therocrotaphous. It would be incongruous to relate two groups of animals in which the crania are of such widely varying types as are the skulls of the turtles and plesiosaurs.

There is a similarity in the mode of life of the two groups, since both are largely of littoral habits. The similarity of "form and habits of these two orders of animals has been due solely to parallel evolution, to similar aquatic conditions." (Williston.) There is decidedly more similarity in the form and mode of life of the ancient ichthyosaurs and the modern dolphins, but no one has ever seriously considered relating these two groups.

The relationship between the turtles and plesiosaurs has therefore been based, in large part, on misconceptions, and the animals do not have the structures on which the greater claims for affinity have rested. "The plesiosaurs could not have been derived from any ancestors that might by the widest stretch of the imagination be called Chelonia or Chelonia-like. Nor could the turtles have come from any forbears even suggesting the sauropterygian structure" (Williston).

14. Williston, 1907, Proc. U. S. Nat. Mus., vol. 32, p. 488.

SUMMARY.

1. The grounds on which have been based the relationship between the turtles and plesiosaurs are (1) the elongate character of the neck and tail claimed for certain turtle embryos; (2) the presence of epiphyses on the long bones; (3) the fusion of the procoracoid to the scapula in the two groups; (4) the possession of teeth in the two groups; (5) the girdles of the plesiosaurs have been compared to the plastron of the turtles; and (6) the similarity in form and habits of life.

2. There are but eight segments in the neck of the turtle embryos examined. There are from thirteen to seventy-six cervical vertebræ in the plesiosaurs, according to Williston.

3. There are no epiphyses on the long bones of either turtles or plesiosaurs. The structures called "epiphyses" are the endochondral cones found in all groups of the Sauropsida.

4. The scapula of the turtle is a single element and the procoracoid is not present. The method of formation of the element is greatly different in the two groups.

5. The elements of the pectoral and pelvic girdles in the plesiosaurs are not homologous with the plastron of the turtles.

6. The structure of the skull and the entire organization of the animals is proof against relationship between the two orders.

7. The similarity of form and habits of life are due to parallel evolution and adaptation for existence under similar conditions.

I am indebted to Dr. S. W. Williston for many valuable suggestions and for several references. It was at his instance that the study was first undertaken.

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KANSAS UNIVERSITY SCIENCE BULLETIN.

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DESCRIPTION OF THE SKULL AND SEPARATE CRANIAL BONES OF THE WOLF-EEL (*ANARRHICHTHYS OCELLATUS*).

BY L. A. ADAMS.

(Contribution from the Zoölogical Laboratory, No. 183.)
Submitted in partial fulfilment of the requirements for the degree of Master of Arts.

Plates XXV to XXXVI.

CONTENTS.

WOLF-EEL (*Anarrhichthys ocellatus*).

THE skull here described is that of *Anarrhichthys ocellatus*, or wolf-eel. The *Anarrhichadidæ* proper are found in the northern waters, few coming farther south than the fiftieth parallel, and indeed most of them are found within the Arctic circle. The subfamily *Anarrhichthys* is found farther south, and the species described was taken at Monterey Bay, California.

The description from Jordan and Evermann's "Fishes of North and Middle America" is as follows:

"Family *Anarrhichadidæ*, p. 2445, vol. III.

"Body oblong or elongate, covered with rudimentary scales; no lateral line. Head scaleless, without cirri, its bones very thick and strong, the profile strongly decurved. Mouth very large, oblique, the jaws anteriorly with very strong conical canines; sides of lower jaw with very strong molar teeth, which shut against a series of very coarse molars on the palatines; vomer solid, armed with very strong molar teeth, the dentition adapted for crushing sea-urchins and mollusks. Gill membranes broadly united to the isthmus; no pyloric cæca. Dorsal fin high, composed entirely of flexible spines; no ventral fins; pectoral fins broad, placed low. Large carnivorous fish of the northern seas. Two genera and about six species known."

(Blennidæ, pt., Günther, Cat. iii, 208-211, 1861.)

The species *Anarrhichthys ocellatus* is found along the Pacific coast in the bays and inlets. These fish live on sea-urchins and sand-dollars, for which food their dentition is well adapted. They are very vicious, and when taken into a boat will snap their jaws very much like a dog or wolf, so they are well named wolf-fish. They are eel-shaped, and are sometimes called wolf-eels. The following is the description of this fish in Jordan and Evermann (*Anarrhichthys ocellatus* Ayres, wolf-eel):

"Head 11, depth 15 D.CCL; A. 233; P. 19. Body elongate, formed as in an eel; the head and jaws very strong. Pectorals broad, more than one-half head; longest spine, dorsal, one-half head. Color dark greenish, the body and dorsal fin everywhere covered with round, ocellated black spots of various sizes, the light markings forming reticulations around the spots; head paler, with reticulations of a finer pattern; anal pale edged. Length, 5 to 8 feet. Pacific coast, from Monterey Bay north to Puget Sound. It feeds chiefly on sea-urchins and sand-dollars. (Ocellatus, with eye-like spots.)"

(*Anarrhichthys ocellatus* Ayres, Proc. Cal. Ac. Nat. Sci., 1855, 31, San Francisco; Jordan and Gilbert, Synopsis, 1893, 782; Jordan and Starkes, Fishes Puget Sound, 1895, 848.)

GENERAL DESCRIPTION OF THE SKULL.

A side view of the skull is shown in plate XXV, figure 1. From this some idea may be obtained of the great strength of the jaws, with their dentition. The front part of the jaws is

armed with large canine-like teeth, conical in shape; farther back, on the vomer and palatines, are the large, rough molars or grinding teeth. The posterior part of the mandible is also armed with large teeth.

The length of the skull is very little greater than the depth; the width is slightly less than the length.

The skull is laterally compressed and very thin on the posterior part of the dorsal edge. Both the frontal and the parasphenoid are drawn out into knife-like edges on the posterior part of the dorsal and ventral portion of the bones. The following bones are noted from this view:

1. Supraoccipital.
2. Exoccipital.
3. Basioccipital.
4. Epiotic.
5. Prootic.
6. Alisphenoid.
7. Sphenotic.
8. Pterotic.
9. Parietal.
10. Opisthotic.
11. Parasphenoid.
12. Frontal.
13. Ethmoid.
14. Prefrontal.
15. Vomer.

The occipital region of the skull is very interesting in its structure, and has a peculiar arrangement of the bones, a great deal like some of the fossil forms of the Cretaceous. This may be seen in plate XXVIII, figure 4. The supraoccipital is placed in between the parietals, and the epiotics are immediately below it, forming a part of the foramen magnum. Ventral to the epiotics are the exoccipitals, the opisthotics extending posteriorly from them.

TEETH.

The teeth are remarkable for fish teeth, and are the most striking thing noticed in this fish. They are of two kinds, the canine-shaped and the heavy molar type. The conical teeth are long and pointed and the grinders are rough and very heavy.

Teeth are found on the following bones: Premaxillæ, vomers, palatines and dentaries; the maxillæ bearing no teeth. The number of teeth is not constant and varies greatly in different specimens. In three specimens they occur as follows: Premaxilla, 8-9; vomer, 9-10; palatine, 5-7; dentary, 11-16; the total number in these three skulls being 66-86. The largest teeth are on the vomer. They are rounded and very heavy and furnish much of the grinding surface.

The palatines are found on each side of the vomer and are well supplied with teeth. The teeth on the mandibles are so placed that they work against those of the palatines and vomer, the mandible being inclined inward. Most of the teeth on the

premaxillæ are canine in form, those at the posterior being small and rounded. There are six to eight of the sharp teeth on the mandibles and about the same number on the two premaxillæ. The teeth are not placed in sockets, but, on the contrary, are hollow and are placed on cones. These cones are ridged in a neat pattern, and the base of the tooth corresponds to it, helping to hold the tooth firm.

The canine-shaped teeth are the most firmly anchored, as they would have the most strain on them. They are hollow for about one-fourth of their length and the cone is correspondingly lengthened. The heavy molars are only slightly concave at the base, but to offset this the cone is very deeply ridged and thus holds the tooth firm. Even after maceration most of them will be found in position.

Minute Structure. (See plate XXVIII, figs. 7, 8.)

The structure is quite complex for a fish tooth, there being thin layers of enamel and dentine. A longisection (see plate XXIX, fig. 9) shows many canals radiating toward the periphery. The canals start from a cavity at the apex of the concavity of the base, and all extend upwards and outwards toward the periphery, where they branch out, forming a network under the enamel. A transverse section (plate XXIX, fig. 10) shows the canals in cross-section, and also a longisection of some of them where they are curving outward to the periphery. The teeth do not show any striations under the lens, but are smooth and polished on the sides, the upper portion being roughened by use. The sides are ridged near the base and correspond to the outline of the cone on which they are placed. The pattern of the cone is so marked that it is easy to replace the teeth on the right cones, even after they are removed and misplaced. (See plate XXVIII, fig. 8.)

DETAILED DESCRIPTION OF THE INDIVIDUAL BONES OF THE SKULL.

The skull is made up of the following bones and they are described in this order:

1. Supraoccipital.	7. Parietal.	13. Prefrontal.
2. Exoccipital.	8. Pterotic.	14. Ethmoid.
3. Basioccipital.	9. Sphenotic.	15. Vomer.
4. Epiotic.	10. Alisphenoid.	16. Suborbitals.
5. Prootic.	11. Parasphenoid.	17. Hyomandibular.
6. Opisthotic.	12. Frontal.	18. Metapterygoid.

19. Symplectic.	23. Palatine.	27. Dentary.
20. Quadrate.	24. Maxilla.	28. Articulare.
21. Mesopterygoid.	25. Premaxilla.	29. Angulare.
22. Pterygoid.	26. Mandible.	30. Preopercular.

SUPRAOCCIPITAL. (Plate XXVIII, fig. 4; plate XXX, figs. 16, 17, 18, 19.)

The supraoccipital is wedged in between the parietals. It is roughly a triangular inverted pyramid, with the base forming the superior posterior part of the skull. The superior angle of this bone is drawn out into a slight crest, fitting between the parietals.

Posterior Face. (Plate XXX, fig. 16.)

The base of the pyramid is triangular in outline and quite deeply concave. The two lateral edges are drawn out thin and fit against the inner face of the parietals. At the lower part of the face there is a forficate process, which overlaps and articulates with the epiotics.

Ventral Face. (Plate XXX, fig. 19.)

The ventral portion of the pyramid forms the posterior half of the roof of the brain-cavity. This is narrowed down anteriorly, a thin tongue fitting in between the sphenotics. It is straight antero-posteriorly, but the sides are drawn down at an angle. A slight ridge extends along the bone longitudinally. This face is double, a thin disc being raised upon it, attached in the center, the edges free, forming a surface for the brain-cavity. This surface is not smooth, but is marked by longitudinal ridges, pits and cavities. (See plate XXX, fig. 19.)

Lateral Face. (Plate XXX, fig. 17.)

The lateral faces are triangular in outline. They are in two planes, the posterior inclining outward and backward, the other outward and downward. They articulate with the inner face of the parietal.

Articulations.

The supraoccipital has four articulations: Its anterior edge with the posterior edge of frontal, this edge fitting into a groove on the posterior edge of frontal. Laterally it articulates with the pterotics, the parietals and the inferior posterior portion of the epiotics.

EXOCCIPITAL. (Plate XXXI, figs. 32, 33, 34.)

The exoccipitals are paired bones in the caudal region of the skull, but also have a place in the sides. The lateral face of the bone is hexagonal, with the longest side placed caudally. Posteriorly it is hour-glass shaped, irregular and narrowed in the middle from the inner side, and the lower edge is cut off transversely at the expense of the inner edge. It forms about five-sixths of the boundary of the foramen magnum.

Outer Face. (Plate XXXI, fig. 32.)

The outer face is hexagonal, though far from regular. It is slightly concave, and is marked by a foramen placed almost in the middle of it which extends obliquely through the bone. From this foramen a groove passes posteriorly, bisecting the caudal border. The edges of the outer face are very irregular, being drawn out into numerous points.

Inner Face. (Plate XXXI, fig. 34.)

The inner face is irregular, the lower posterior part articulating with the cervical vertebræ. It points downward and inward. The middle of the inner face is marked by two foramina, one extending obliquely through it to the middle of the outer face; the second is posterior to it. The openings to these foramina are in a depression. On the superior posterior portion of the face there is another protuberance, which is pointed posteriorly, starting at about the middle of the inner face and articulating with the epiotic.

Articulations.

The exoccipital has six articulations: Ventrally with the basioccipital; anteriorly with the basioccipital and the prootic; superiorly with the pterotic and epiotic and with the other exoccipital.

BASIOCCIPITAL. (Plate XXX, figs. 20, 21, 22, 23.)

The basioccipital is a very irregular bone. It has five faces to consider.

Posterior Face. (Plate XXX, fig. 20.)

The posterior face of the basioccipital is concave and is marked by a number of concentric rings. Slightly above the center of the concavity there is a small pit. This part of the bone articulates with the neck vertebræ. The longest axis extends dorso-ventrally.

Lateral Face. (Plate XXX, fig. 22.)

The lateral faces are rather smooth, but are depressed at the posterior edge, this edge being drawn out laterally to enlarge the posterior face.

Dorsal Face. (Plate XXX, fig. 21.)

The upper or dorsal face forms the postero-ventral part of the brain-case. It is set up above the rest of the bone, as are all of the bones forming a part of the brain-case. It is marked by numerous pits and cavities.

Anterior Face. (Plate XXX, fig. 21.)

The anterior part of the basioccipital is marked by a deep groove. It inclines ventrally and posteriorly at the expense of the ventral face. The lower part of the groove has a thin tongue of bone extending about half way to the dorsal edge. This groove articulates with the parasphenoid.

Articulations.

The basioccipital has six articulations: With the parasphenoid, prootics, exoccipitals and the first cervical vertebra. It articulates with the parasphenoid by the groove in the anterior face, with the prootics and exoccipitals by the edges, and the posterior face with the cervical vertebra.

EPIOTIC. (Plate XXXI, figs. 29, 30, 31; plate XXVIII, fig. 4.)

The epiotics are paired bones in the posterior part of the skull. They are placed ventral to the supraoccipital, against the pterotics, their anterior face forming a part of the brain-cavity. They are twice as long as wide, the long axis of the bone being placed transversely across the occipital region of the skull. The epiotics have three faces to consider.

Inner Face. (Plate XXXI, fig. 29.)

The inner face is roughly square in outline and the part of the bone forming the brain-case is covered with a thin plate of bone, as usual. This disc is pitted and is generally concave. The face articulating with the pterotics is concave and is marked with numerous ridges which fit into corresponding grooves on the pterotic.

Outer Face. (Plate XXXI, fig. 30.)

The outer face is concave on the short axis and is roughly rectangular in shape, the outer end being narrowed down to a rounded projection. The face articulating with the pterotic is at right angles to that forming a part of the brain-case.

Articulations.

The epiotic has six articulations. The two epiotics do not meet on the median line. In the dry skull they seem to have been united by a cartilage. They articulate with the supraoccipital on the dorsal edge, a thin tongue of bone from the supraoccipital overlapping its dorsal inner edge. They articulate with the pterotics anteriorly, the surfaces being roughened by ridges and grooves. The ventral and exterior edges articulate with the opisthotic and the exoccipital. The ventral edges of the epiotics form the dorsal border of the foramen magnum.

PROOTIC. (Plate XXIX, fig. 11; plate XXX, figs. 12, 13, 14.)

The prootics are ventral to the sphenotics, posterior to the parasphenoid and superior to the basioccipital and parasphenoid, the latter extending posteriorly under it. In shape it is roughly pentagonal but is very irregular in outline, the ventral edge being marked by many serrations.

Outer Face. (Plate XXX, fig. 14.)

The outer face is marked by a long, irregular ridge, extending from the posterior superior portion, where it is quite prominent, down to the antero-ventral edge. At the middle of this ridge is a large foramen, extending through the bone and coming out at the superior edge. This foramen is for a part of the fifth nerve. On the superior anterior part of the bone is another protuberance, which aids in forming the pit for the hyomandibular head.

Inner Face. (Plate XXX, fig. 12.)

The inner face also is quite irregular. It forms the lower posterior side of the brain-case. On the lower edge of the face is a prominent slit with projecting lips, starting at the middle of the anterior border and curving posteriorly and ventrally. At the posterior edge it opens into a cavity in the bone. The foramen for the part of the fifth nerve may be seen on the ventral edge. When the bones are in position the two slits are in juxtaposition, forming a cavity through one bone and into the other at the ventral part of the brain-cavity.

Articulations.

The prootic has five articulations: Anteriorly with the parasphenoid and sphenotic, ventrally with the parasphenoid, posteriorly with the basioccipital, exoccipital and pterotic. The two prootics touch each other on the median line.

OPISTHOTIC. (Plate XXVI, fig. 2; plate XXX, fig. 15.)

The opisthotics are small bones, rectangular in shape, very thin and with two faces. They lie on the outer faces of the exoccipitals, which have slight depressions to receive them. The superior edges fit into grooves in the ventral part of the pterotic. They extend posteriorly from the exoccipitals.

PARIETAL. (Plate XXVI, fig. 2; plate XXVII, fig. 3; plate XXXIII, figs. 49, 50, 51, 52.)

The parietals and the pterotics are united in this skull, the suture being entirely obliterated and showing only as a ridge on the exterior face of the bone. The shape of the parietal, considering it separately, is a little irregular.

Outer Face. (Plate XXXIII, fig. 49.)

The outer face is concave and smooth, with the exception of the ridge marking the division line between pterotic and parietal.

Articulations.

The parietal has four articulations (considering it as a separate bone). It articulates with the supraoccipital and frontal on the inner face, its anterior edge being fitted in between the sphenotic and frontal; the ventral edge is joined to the pterotic.

PTEROTIC. (Plate XXVI, fig. 2; plate XXIX, fig. 11; plate XXXIII, figs. 49, 50, 51, 52.)

The pterotic is marked by a groove along the ventral part to contain the articulating portion of the hyomandibular. Its shape is triangular.

Inner Face. (Plate XXXIII, fig. 50.)

The inner face of the pterotic and parietal is divided, the pterotic, or ventral half, forming a part of the brain-case, and the dorsal half only an articulating surface.

Outer Face. (Plate XXXIII, fig. 49.)

The outer face is concave, smooth, and triangular in shape, with the base ventral. The parietal is placed on the anterior superior edge.

Anterior Face. (Plate XXXIII, fig. 51.)

The anterior face is at right angles to the outer face and has a long ridge extending along its surface, forming a groove for the hyomandibular. This face is roughly rectangular in shape.

A small groove for the opisthotic is seen close to the inner edge of the face.

Articulations.

Considering it separately, the pterotic has seven articulations. It articulates with the parietal dorsally; anteriorly with the sphenotic and epiotic on its inner posterior face; ventrally with the exoccipital, prootic and hyomandibular.

SPHENOTIC. (Plates XXV, XXVI, XXVII; Sph. Plate XXXIII, figs. 46, 47, 48; plate XXIX, fig. 11.)

The sphenotic extends out farther laterally than any other bone in the skull. It is posterior to the frontal and alisphenoid and extends outward and backward. It is hexagonal in shape. The posterior edge is parallel to the long axis of the skull and its posterior edge is at right angles to the long axis, and its lower edge extends anteriorly and superiorly, narrowing down to a blunt point. It has three faces, an outer, inner and posterior.

Outer Face. (Plate XXXIII, fig. 46.)

The outer face is smooth, concave from the posterior to the anterior edge and convex from the superior to the inferior edge. The posterior part is almost at right angles to the anterior, as the bone inclines outward, thus making the posterior face. The posterior edge is drawn out into a sharp ridge, making the posterior face a long groove, wide at the inferior part and narrowing rapidly at the superior portion. The lower part points downward and backward and forms the greater part of the pit for the hyomandibular, the prootic forming the rest of the cavity.

Inner Face. (Plate XXIX, fig. 11; plate XXXIII, fig. 48.)

The inner face forms a part of the brain-case and is about three times as long as wide, and is narrowed down to the anterior end and rounded posteriorly. There is a tongue on the middle of the ventral edge which fits into a groove on the prootic. This face is slightly concave, and is built up above the rest of the bone. It has a prominent depression at the posterior part. All of the bone forming a part of the brain-case is pitted and honeycombed.

Articulations.

The sphenotic has six articulations. Anteriorly it fits into a notch on the posterior part of the frontal; the antero-ventral

edge with the alisphenoid and parasphenoid; its ventral edge with the prootic, parasphenoid and hyomandibular; posteriorly with the pterotic; dorsally with the parietal and frontal.

ALISPHENOID. (Plate XXVI, fig. 2; plate XXIX, fig. 11; plate XXXIII, fig. 45.)

The alisphenoid is a thin bone, placed at the angle where the parasphenoid and frontal separate posteriorly. It is triangular in shape, with the base of the triangle placed dorsally. It is less than 2 mm. in thickness, and is merely a disc of bone. It has three articulations: Anteriorly with the parasphenoid and frontal, these overlapping its outer face so that only about one-third shows on the outside of the skull, superiorly with frontal, ventrally with parasphenoid, and posteriorly with sphenotic.

PARASPHENOID. (Plate XXVI, fig. 2; plate XXXII, figs. 40, 41.)

The parasphenoid is the second largest bone in the skull, the frontal being the largest. Its shape is irregular.

Ventral Edge.

The ventral edge is knife-like, forming a sharp keel at the posterior part. Anterior to this keel the bone widens out into a shallow trough or groove with thin edges, making a ventral face for the articulation of the vomer. The bottom of this groove is rough and has in it a smaller groove extending along the whole length of the articulating surface and fitting a tongue-like projection on the vomer. At the posterior end the parasphenoid widens out abruptly and then rapidly narrows, making a beveled surface, over which the basioccipital fits. There is a deep, narrow groove in the posterior superior border of the median line, and a thin tongue from the basisphenoid fits into it.

Dorsal Edge. (Plate XXXII, fig. 41.)

The dorsal edge is more irregular than the ventral. It expands and extends dorsally and outward. About one-third of the dorsal edge is raised in this way. It starts to expand immediately anterior to the articulation of the basioccipital, and ends anteriorly where the upper edge dips down ventrally. These expanded, up-growing wings are cut by a deep slit, reaching almost to the floor of the groove between them. The narrow part, posterior to this, articulates with the sphenotic, and the part anterior with the alisphenoid and frontal. An-

terior to the articulation with the frontal, the expanded edge drops rapidly and forms an acute projection on each side, extending toward the front; anterior to these the edge continues regular. This anterior part of the parasphenoid extends forward as a projection. The upper part is marked by a thin ridge extending along the median line. This projected anterior end of the parasphenoid flares out inferiorly, the part articulating with the vomer being wider than the upper surface. The groove between the upper edges of the parasphenoid is quite deep and narrow.

Faces.

The faces of the parasphenoid are rather smooth but marked by fine striations. At the posterior part of the expanded upper edge there is a sharp ridge, pointing posteriorly, and extending to the ventral edge; immediately posterior to the ridge, on the superior edge, there is a foramen of some size, extending into the bone anteriorly.

Articulations.

The parasphenoid has eight articulations. The anterior part articulates ventrally with the vomer, laterally with the prefrontals and anteriorly with the ethmoid. On the rest of the dorsal edge it articulates with the following, in order: frontal, alisphenoid, sphenotic, prootic and basioccipital.

FRONTAL. (Plate XXV, fig. 1; plate XXVI, fig. 2; plate XXVII, fig. 3; plate XXIX; plate XXXI, fig. 35; plate XXXII, fig. 36.)

The frontal is unpaired, and is the largest bone in the skull. Its superior edge is drawn out at the posterior part into a thin crest. Anteriorly it widens out laterally. The ventral surface has two wings articulating with the corresponding upward growth on the parasphenoid. The frontal has three faces, a postero-lateral, a dorsal, and the anterior beveled faces.

Lateral Face. (Plate XXXI, fig. 35.)

The lateral face is at the posterior half of the bone. From the thin dorsal edge it is inclined outward and posteriorly, articulating with the sphenotic. A rounded ridge extends up from this articulation to the anterior edge of the face, where it fades out. This face is marked with striations.

Dorsal Face. (Plate XXVII, fig. 3; frontal.)

The edges are gently concave, the face narrowing at the anterior end. A ridge extends along the median line of

the face, and between this ridge and the edge the face is depressed. Starting at the anterior edge of the face are two large cavities which extend posteriorly. The whole face is honeycombed, the pits extending in regular lines. The anterior end of the bone is forficate, and the articulation with the ethmoid is formed in this way, the posterior part of the ethmoid being wedge-shaped and fitting into this cavity.

Lateral Face (anterior). (Plate XXXI, fig. 35.)

The anterior lateral face is formed by the anterior end being beveled toward the ventral edge. This face is concave both ways and at the posterior end turns out laterally. There are two cavities at the postero-ventral part of each face, extending posteriorly into the bone. Just posterior to this face there is a depression for the articulation of the suborbital ring; at the center of this depression there is a foramen, extending posteriorly also. The ventral end of the frontal is hollow and sheaths the ethmoid in this cavity.

Articulations.

The frontal has eight articulations: Posteriorly with the parietal, by overlapping it; with the supraoccipital by a sharp groove in the posterior end; with the sphenotic by this bone overlapping the frontal; ventrally with the alisphenoid, which lies against the ventral wing on the inside; with the parasphenoid by the drawn-out ventral edge; with the suborbitals at the posterior part of the enlarged anterior end of the frontal; with the ethmoid anteriorly, and with the prefrontals at the anterior end of the lateral faces.

PREFRONTAL. (Plates XXV, XXVI, XXVII; plate XXXII, figs. 37, 38, 39.)

The prefrontals are irregular bones lying on each side of the ethmoid. The posterior face is concave and points posteriorly and dorsally. This face is smooth and has a large process, springing from the ventral inner portion, which articulates with the ethmoid, parasphenoid and the other prefrontal. There are two depressions in the outer edge, immediately ventral to the smooth dorsal face, which articulates with the suborbital ring; one depression or notch is cut out at the expense of the upper edge, and the posterior notch at the expense of the lower.

The inner ventral edge drops ventrally and forms a large process for articulation on the ventral and inner face. This process is very irregular. At the anterior part there is a

small, raised tubercle, which has a small facet for the articulation with palatine.

Articulations.

The prefrontal articulates with the ethmoid by two articulations, making a large foramen between the two. It articulates with the other prefrontal on the median line. The inner face is very irregular. The outer edge of the dorsal part articulates with the suborbital ring. Posteriorly it articulates with the pterygoid, and on the inner ventral edge it has a slight articulation with the vomer. The palatine fits on a slight tubercle which has a small facet; this is on the ventral part. The dorsal part of the prefrontal forms the anterior part of the orbit.

ETHMOID. (Plate XXV, Eth. plate XXVI, plate XXVII, Eth. plate XXXIII, figs. 42, 43, 44.)

The ethmoid is wedge-shaped, with the antero-ventral part drawn down ventrally. It articulates with the frontal by fitting into a cavity in the anterior end.

Anterior Face. (Plate XXXIII, fig. 44.)

The face is divided by a sharp ridge extending dorso-ventrally through its median line, making two concave surfaces, one on each side, which articulate with the premaxillæ. The lateral edges are drawn out laterally, forming two small wings, their ventral edge being a little below the center of the bone. Below these wings this face slopes rapidly posteriorly. A dorsal view of the ethmoid shows a kite-shaped outline. The dorsal surface is rather flat anteriorly for about one-third of its length, where it becomes sharp and keeled on the dorsal edge. The whole bone is compressed laterally, the dorsal edge having a prominent keel occupying its middle third.

Posterior.

A posterior view shows the upper part to be rather cone-shaped—a cone rounded at the ventral edge and sharp on the dorsal edge. At the ventral anterior part it has two articulating surfaces.

Articulations.

The ethmoid has five: Anteriorly with the two premaxillæ; posteriorly with the frontal, by the cone-shaped part being sheathed in this bone; on the postero-ventral face with the two prefrontals and parasphenoid; ventrally with the vomer.

VOMER. (Plate XXVI; plate XXX, fig. 24.)

The vomer is a large, stout bone, and is one of the strongest in the skull. It is boat-shaped, with the prow pointed posteriorly.

Lateral Faces. (Plate XXVI.)

The lateral faces are convex both ways and are wider anteriorly than posteriorly. The postero-superior edge is drawn out laterally and dorsally, making an articulation for the ethmoid and the prefrontals. There is a small tubercle on the anterior part near the dorsal edge, the articulation for the long, slender maxilla. The dorsal posterior half of the face is narrowed down, the parasphenoid fitting over it. These lateral faces are marked by several pits. There is a prominent foramen posterior to the articulation with the prefrontal, and several along the ventral edge, just above the teeth.

Ventral Face. (Plate XXX, fig. 24.)

The ventral face is the tooth-bearing surface and has nine to eleven teeth.

Dorsal Face.

The dorsal face is very irregular, and is covered with pits and cavities, large and small. A thin tongue of bone extends along the median line longitudinally, fitting into a groove in the parasphenoid. The anterior half of this face is raised and extended out laterally, having a dentate edge which articulates with the prefrontals and the ethmoid.

Articulations.

The vomer has four: On its antero-lateral part it has a small tubercle which articulates with the maxilla; dorsally with the ethmoid and the prefrontals; posteriorly with the parasphenoid.

THE SUBORBITAL RING. (Plate XXV, fig. 1.)

The suborbital ring is made up of seven bones. The largest is at the anterior end of the ring, and they gradate down to the fifth, which is the smallest. They articulate with the frontal and prefrontal. The frontal extends out laterally, and a double notch is formed; by this the anterior suborbital articulates with it. The two suborbitals at the ends are the largest of the ring.

Suborbital 1.

This is roughly rectangular in shape, the dorsal edge being shorter than the ventral, as the two dorsal corners are cut off. A section of the bone is triangular at the posterior end, the anterior end being thin. The lateral face is convex on the long axis, and is marked by five foramina, the three larger connecting with each other by a canal. All of the suborbitals have at least two foramina, and they are all connected and make a canal through the whole ring. The upper face of the first is indented by a notch which fits over a double notch on the prefrontal, giving the ring a good articulation at the anterior end. The articulation of suborbital 1 and suborbital 2 is triangular. Suborbital 1 is cut off posteriorly at the expense of the dorsal face, making a triangular face for the articulation with suborbital 2.

Suborbitals 2, 3, 4.

These are very much alike in shape. The ventral edge of each is about twice as long as the dorsal, making a notch in the posterior end of each, into which the next suborbital fits. All three are triangular in section, with the base of the triangle ventral. All have a foramen at each end, posterior and anterior, and all are connected by a canal. Each of the suborbitals projects posteriorly under the succeeding bone.

Suborbital 5.

The fifth is differently shaped and does not enter into the ventral face of the ring. The sixth suborbital sends a projection anteriorly to meet the posterior projection of suborbital 4, so that suborbital 5 is above.

Suborbital 6.

The sixth meets the projection of the fourth on the ventral border of the ring. It is about twice as long as wide, the posterior end being irregular, making a dentate suture with the seventh.

Suborbital 7.

The seventh, and the last of the ring, is wider at the posterior end than at the anterior. It articulates with the frontal, which has a deep depression for this articulation. There is a canal on the frontal, continuous with the canal extending through the ring. The whole ring is covered with small tracings, which do not show in the drawing.

SUSPENSORIUM OF THE MANDIBLE. (See plate XXV.)

The suspensorium of the mandible includes three bones—quadrate, symplectic and hyomandibular.

HYOMANDIBULAR. (Plate XXV, fig. 1; plate XXXIV, figs. 55, 56.)

The hyomandibular is a flat bone, rectangular dorsally, with a long projection extending ventrally. The outer face is convex with a slight concavity in the center of the lower two-thirds of the bone. The inner face parallels the outer and is consequently concave. The dorsal edge is almost straight and articulates with the pterotic. The dorsal anterior corner is drawn out into a slight knob, which fits into a cavity in the ventral posterior part of the sphenotic.

The anterior edge is slightly concave in outline and articulates with the metapterygoid. The ventral edge is extended ventrally, a narrow strip of bone, rounded on the posterior edge and thin on the anterior. The ventral edge is cut off squarely and articulates with the symplectic.

The posterior edge is indented by a deep notch, into which the preopercular fits. The dorsal edge of this notch is drawn out posteriorly into a rounded process which articulates with the opercular.

The inner face is concave and marked with striations. In the dorsal part it has two large foramina and several small ones. The most ventral foramen extends through the bone and comes out on the exterior face in the ridge which extends down the bone.

The outer face shows more irregularities than the inner. A ridge starts on the dorsal posterior edge and extends in a diagonal direction down the projection. The anterior part of this ridge is sharp and at right angles to the rest of the bone, really making a narrow face. Another slight elevation starts at the dorsal anterior corner, at the head of the hyomandibular, and extending diagonally, meets the long ridge. From the articulation with the opercular there is a ridge extending anteriorly and dorsally. The only foramen in the bone is placed a little ventrally to the median line. It is on the ridge and has a long fossa extending up to it. It goes through the bone and comes out on the inner face.

Articulations.

The hyomandibular articulates dorsally with the pterotic, prootic and sphenotic. Anteriorly, with the metapterygoid,

the posterior edge of which has a slight groove into which the anterior edge of the hyomandibular fits. Ventrally it articulates with the symplectic. Both bones are concave on the articulating surface, so they are probably connected by a cartilage. Posteriorly it articulates with the preopercular, which fits into the notch on its posterior edge. It also articulates with the opercular on this edge by a rounded projection.

METAPTERYGOID. (Plate XXV, Metap.; plate XXXI, figs. 27, 28.)

The metapterygoid is a thin bone, rather triangular in shape, with the edges a little convex. The base of the triangle corresponds to the base of the bone. The outer face is striated, very thin anteriorly and thickened posteriorly. The posterior edge is grooved to receive the anterior edge of the hyomandibular. This face is concave and is slightly twisted to the posterior at the antero-ventral point.

The inner face is smooth, is convex dorso-ventrally, and slightly concave along the lower part of the bone.

Articulations.

It articulates posteriorly with the hyomandibular. The hyomandibular fits into a groove in the posterior edge of the bone. At the lower part it has a slight articulation with the dorso-anterior edge of the symplectic. The anterior edge is free, except at the ventral part, where it is rounded, and articulates with the mesopterygoid by overlapping its outer face. Ventrally it articulates with the anterior dorsal edge of the quadrate. The anterior part of the articulation is merely the thin edges meeting, but at the posterior part of the articulation both bones thicken and are concave on the articulating surface.

SYMPLECTIC. (Plate XXV, Sym.; plate XXXV, fig. 57.)

This is a wedge-shaped, triangular bone, with the base of the triangle placed dorsally. The faces are fairly smooth and are not in any way marked. The anterior edge is beveled at the expense of the outer face and is slightly grooved. The posterior edge is irregular. With the bones in position only about two-thirds of the symplectic can be seen from the lateral view of the skull, the other third being sheathed in the quadrate. On the inner side all of the bone can be seen. It fits in a wedge-shaped notch on the dorsal posterior edge of the quadrate and is firmly fixed there, about two-thirds of the bone being in this sheath,

Articulations.

It articulates dorsally with the hyomandibular. The lower two-thirds is sheathed in the quadrate and the dorsal one-third articulates with metapterygoid. Posteriorly it articulates with the quadrate on the lower third of the posterior edge, the other one-third being free.

QUADRATE. (Plate XXV, Quad.; plate XXXV, figs. 57, 58.)

The quadrate is a peculiarly shaped bone, occupying the angle of the suspensorium. The posterior part of the bone is heavy and the anterior part is thin and fan-shaped. There is a notch on the inner side where the symplectic is sheathed.

The outer face is rod-like at the posterior part, and the anterior part is thin. Anterior to the rod-like posterior end the face is pushed inwardly so that the fan-shaped portion is farther in than the heavy part at the posterior. The face is marked with small ridges and numerous foramina. All converge at the posterior ventral angle. The inner face of the bone is striated and has numerous ridges like the outer face. On the anterior edge there is a depression, dropped below the rest of the face and forming an articulation. This depression occupies about one-third of the face. It narrows down ventrally and furnishes a good articulation for the pterygoid. The ventral posterior angle is pushed in, forming an articulation with the mandible.

The posterior part of the quadrate is very heavy and solid. It is smaller dorsally, swelling out a little below the median line, then narrowing again, forming a constriction above the lower ventral part, which is the heaviest part of the bone. The posterior face of this part is deeply grooved, the groove fitting over the preopercular. The deep notch between the rod and the fan-shaped part is cut out at the expense of the inner face, only half of the notch showing from the outer view of the quadrate.

The articulation for the mandible is in two parts, divided by a constriction. This articulating surface points slightly anteriorly. The larger part of the articulation is at the ventral part of the rod. The lower part is expanded and makes a large convex surface.

Articulations.

The quadrate has six articulations: Anteriorly with the pterygoid by overlapping it, a notch being cut out of the quadrate to receive it; with the mesopterygoid at the anterior dorsal angle, the edges resting against each other; superiorly with the metapterygoid, the edges meeting; with the symplectic by sheathing it; posteriorly with the preopercular, and ventrally with the mandible.

MESOPTERYGOID. (Plate XXV, fig. 1; plate XXXI, figs. 25, 26.)

This is a thin bone between the metapterygoid and pterygoid. It is expanded at the posterior dorsal part, forming a thin posterior end. Its ventral edge is almost a straight line, but a little convex. The anterior end is quite narrow. The expanded part is quite thin on the edge, and rounds over from the posterior to near the center, where it drops down abruptly, making the narrow anterior part.

The lateral face is concave from posterior to anterior, the posterior part is folded and waved. The inner face is convex, the anterior dorsal edge twisted so that it points out laterally, the ventral edge pointing inward.

Articulations.

The mesopterygoid has three articulations, its ventral edge fitting into a groove on the dorsal edge of the pterygoid, posteriorly with the metapterygoid. It has a slight articulation with the quadrate.

PTERYGOID. (Plate XXV Pt.; plate XXXV, figs. 57, 58.)

The pterygoid is a stout bar uniting the quadrate and palatine. The anterior end is heavy and triangular in section, the base of the triangle dorsal, its inner edge inclined a little ventrally. Posteriorly it bends ventrally and laterally, and expands to about twice the depth. The anterior end is narrowed down to a rough point which articulates with the prefrontal. The pterygoid is cut out on the antero-ventral part and also on the lateral part, making an articulation for the palatine. On the dorsal edge the inner part has a deep, angular groove, into which the mesopterygoid is placed, it being grooved also.

The posterior end of the pterygoid is rather thin and is drawn downward and a little outward. Immediately posterior to the place where it turns down a thin plate of bone extends

dorsally, so that the posterior end is slightly forficate. The outer part of this downwardly inclined part is depressed sharply along the upper part of the face, where it fits against the inner face of the quadrate, the edges of this depression being serrated.

Articulations.

It has five: Anteriorly with the palatine and the prefrontal; dorsally with the mesopterygoid; posteriorly with the quadrate. It touches the metapterygoid.

PALATINE. (Plate XXV, Pal.; plate XXXV, fig. 58.)

The palatine is a very heavy, thick bone, and bears teeth on the ventral edge. The bone may be called triangular in shape, with the base dorsal. A long prolongation extends forward and outward from the dorsal outer angle of the bone.

The outer face is slightly concave both ways. The upper dorsal edge is cut down obliquely at the posterior part and is drawn out posteriorly from the ventral side, the posterior part being cut out behind the teeth, and extends dorsally at right angles for a short distance and then runs posteriorly. (Plate XXXV, fig. 57, P.) In front of the anterior end of the oblique dorsal edge the edge dips down and makes a notch, and in front of this the anterior projection starts and extends forward. This prolongation narrows down at the anterior end and becomes quite small.

The inner face is slightly concave both ways. The oblique part is serrated, and is drawn out laterally. On the anterior part of the prolongation at the base there is a small protuberance, which furnishes the articulating surface with frontal.

The dorsal face of the palatine is concave at the posterior half and is inclined obliquely posteriorly. The edges are extended dorsally, making a groove for the pterygoid. Anterior to this articulating surface the bone drops ventrally and then rises, making a notch. The bottom of this is marked by several foramina. Anterior to this the prolongation starts forward.

The ventral face is tooth-bearing and has from five to seven teeth. The teeth are in a single row anteriorly, and posteriorly they may be paired. These are good-sized teeth, and work against those on the mandible as they are close to the vomer, lying on each side of it. All of the palatine teeth have rounded surfaces.

Articulations.

The palatine has two. On the dorsal edge it articulates with the pterygoid, and the anterior part of the inner face with the frontal. The anterior prolongation fits in between the first suborbital and the vomer, but touches neither.

MAXILLA. (Plate XXV, Max.; plate XXXV, figs. 59, 60.)

The maxilla is a long, slender bone, bearing no teeth and having nothing to do with mastication. Its anterior end is elliptical and the posterior end is very thin. The outer face is convex posteriorly and slightly concave at the anterior end. At about four-fifths of the distance to the posterior end the bone is constricted, and back of this it becomes very thin. At the anterior end the bone is drawn down ventrally and forms a head or condyle, which articulates with the vomer.

Articulations.

The maxilla has three articulations. The articulation on the vomer is near the anterior end and the two maxillæ touch each other at the anterior end. The articulation with the premaxilla is along the ventral edge. The ventral part of the condyle fits into a small depression on the inner side of the premaxilla.

PREMAXILLA. (Plate XXV, Premax.; plate XXVIII, figs. 5, 6.)

The premaxilla has a good supply of teeth, most of them being canine-shaped. The number is different, but averages 8 or 9. The first four or five are large and the rest are small and rounded. The anterior tooth is usually single; posterior to this the large ones form a double row, and the remaining small ones a single row.

Outer Face. (Plate XXVIII, fig. 5.)

The premaxilla is shaped in a peculiar manner. The anterior part of the bone is heavy and the long axis is placed dorso-ventrally. At the base of the posterior edge there is a projection which points posteriorly. It narrows down back of the teeth and becomes a spine. This projection is at right angles to the rest of the bone. The outer face is convex and is marked by striations. At the base of the two anterior teeth there are two foramina. The dorsal edge is rounded at the expense of the posterior edge.

The inner face of the premaxilla is rather irregular. The anterior part of the face is smooth and is the symphyseal surface. Posterior to this it is very rough. There is a groove

which extends from top to bottom, cutting off a part of the articulating surface. The bone is depressed dorsally to the teeth and also on each side of the posterior projection.

Articulations.

It articulates with the other premaxilla on the median line; with the ethmoid, its dorsal posterior edge fitting into a concavity on the anterior face of the ethmoid; posteriorly with the maxilla, the condyle of the maxilla fitting into a facet on the premaxilla.

MANDIBLE. (Plate XXV, Man.; plate XXXVI, figs. 61, 62, 63.)

The mandibles, in this family, are well built, and are different from most fish jaws. The two rami are joined by a weak suture, and are held by tissue. The two rami are at an angle of about 45 degrees to each other. The symphyseal surface is rectangular in shape, slightly narrowed at the ventral border. The ventral edge of the mandible is the base of the dentary, and is straight, except at a point near the chin, where it curves slightly ventrally. The anterior edge is gently concave, and also the dorsal border. The dorsal border is the tooth-bearing surface. It is raised up to make a place for the teeth. Posterior to the teeth the mandible is elevated dorsally and ends in the coronoid process. The posterior edge is cut off obliquely at the expense of the dorsal edge. At the lower part is found the articulation for the quadrate.

The outer face is rounded. The greatest width of the ramus is at about the middle of the bone. At the dorsal edge there is a depression ventral to the teeth.

The inner face of the mandible is made up of the inner faces of dentary and articulare. There is a large cavity posterior to the teeth, extending anteriorly. At about the middle the upper part of the face is cut off, and ventrally a long ramus extends posteriorly along the ventral edge of the articulare.

There are three bones in the mandible to be described. The splenial is reduced and is seen merely as a splint, and cannot be described separately. The other three bones are the dentary, articulare and angulare.

DENTARY. (Plate XXV, Den.; plate XXXVI, figs. 61, 62, 63.)

The dentary is the largest bone in the mandible, and in describing it one almost defines the whole mandible. The anterior

edge of the dentary is oblique and the lower edge is cut off by this. The posterior of the dentary is forficate and sheaths the anterior projection of the articulare. The greatest thickness of the dentary is along the median line. Ventral to this it is inclined rapidly inward. Dorsal to the median line it is rapidly depressed and the outer line of the teeth falls inside of the base line of the inner face. This upper depression is posterior to the canine teeth, as they are located where the mandible is rather thick. The outer face is marked by several foramina. Just below the median line there are four. In the depression below the teeth there are two of noticeable size at the anterior part. There is also a foramen in the posterior end of the lower fork of the dentary. The whole face is striated and marked with small holes. At the base of the anterior teeth there is a pit. The ventral line is almost straight, but at the anterior end it is curved upward, making a protuberance for the chin.

The inner face is rather plain and is striated. This face is one plane for the most part. At the middle of the upper part the face is drawn inward so that the teeth are inclined inward. The front is beveled and forms the symphyseal surface. This is formed at the expense of the inner face. Back of the teeth the face is cut out, making the large hollow in the mandible. There is a cavity extending anteriorly into the bone.

The dentary has but two articulations. It meets the other dentary in front, and at the posterior articulates with the articulare. The dentary sheaths the articulare.

ARTICULARE. (Plate XXXVI, figs. 61, 62, 63.)

The articulare is a triangular bone, thick posteriorly and very thin anteriorly, making it wedge-shaped, the anterior point being in the fork of the dentary. The outer face is rounded and is striated. The ventral face is wedge-shaped and rests on the dentary. At the posterior it drops down and makes an articulating surface for the angulare.

The dorsal part is extended upwards in a projection and helps to make the coronoid process. At the posterior end the bone is thick and has articulating surfaces for the quadrate and angulare. Immediately in front of the articulations with the quadrate the bone becomes thin. The ventral face of the articulare, although wide, may be called a shelf, as the upper edge is thin in a horizontal plane.

ANGULARE. (Plate XXXVI, figs. 61, 62.)

The angulare is a small bone placed at the ventral, posterior angle of the mandible. Its anterior end is small, and the posterior part is enlarged and rounded. The bone fits in a depression in the articulare.

The work on this paper was done under the direction of Doctor McClung.

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DESCRIPTION OF PLATES.

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THE ANATOMY OF THE *ACRIDIDÆAN* HEART AND ITS HISTOLOGICAL STRUCTURE.

BY LALIA V. WALLING.

(Contribution from the Zoölogical Laboratory, No. 184.)

Submitted in partial fulfilment of the requirements for the degree of Master of Arts.

Plate XXXVII.

CERTAIN interesting physiological experiments on the heart and respiratory activities in the grasshopper,[1] led to the investigations described in this paper. So many of the experimental results obtained resembled those described by Carlson[2] for *Limulus,* where he proved beyond a doubt the neurogenic theory of heart contraction, that I hoped to show the same for the grasshopper.

On account of the small size of the heart and its delicate structure this has not been an easy task. Many difficulties have beset the work, and while I cannot say beyond a doubt that nerve- or ganglion-cells have as yet been found, it seems worth while to give some account of the methods employed and the results obtained.

This work was pursued under the direction of Dr. C. E. McClung, to whom I am indebted for much valuable assistance. I am also obliged to Doctor Hyde, at whose suggestion this work was undertaken, for many helpful suggestions.

I was able to find very little literature touching on the anatomy of the heart of any of the insects or other invertebrates, and very much less concerning its histological structure. Dogiel[3] described cells which he called ganglion-cells around

1. Walling, L. V., Jour. of Exp. Zoöl., vol. III, No. 4, p. 821.

2. Carlson, E. J., Amer. Jour. of Phys., vol. XII, No. 1, '04, p. 67.

3. Dogiel, Joh., Memoires de L'Academie St. Petersburg, VII series, tome XXIV, No. 10, p. 9.

the heart of the *Corethra larva*. In only a few cases did he find processes on the cells. He also found ganglion-cells in the auricle of the snail's heart.

Ransom,[4] however, thinks Dogiel is mistaken in calling these cells ganglion-cells. Instead he thinks they are "wandering connective tissue" cells, probably the same as the "plasma-cells" described by Brock.[5] He found cells similar to Dogiel's ganglion-cells in the auricle of *Aplysia* and in *Pterotrachea* in the connective tissue all over the body. In *Helix* he found the "plasma-cells" in various stages of division, but in no case did he find *what he could call true ganglion-cells*, or nerve-cells, in the substance of the rhythmically contractile organ, but he did find nerve-fibers. *Octopus* and a tunicate were also examined by him, but with the same results.

In *Aplysia*, Ransom described these cells as being roughly spherical with deeply staining nucleus and a clear, slightly staining cell substance. In *Pterotrachea* the cells are roundish, possess a not very distinct oval nucleus placed near the periphery of the cell, and often a nucleolus. There is no definite capsule. In *Helix* these cells were found in various stages of division. They somewhat resemble cells that I found in the grasshopper, which will be described later.

Ransom also states that other cells which might be taken for nerve-cells are nothing more than ordinary connective-tissue cells. He says: "In no molluscan or tunicate heart examined are ganglion-cells to be found." Foster[6] thinks they do not exist, and Darwin,[7] Ransom and Biederman all say that the snail's heart has no ganglion-cells, although Ransom says nerve-fibers do enter the heart. Dogiel believes them to exist in the auricle.

Among the works of more recent investigators concerning the activity of the heart-muscle of the invertebrates, Carlson's[8] is perhaps the most extensive. Aside from his observation, the majority substantiate the myogenic theory of contraction. Carlson's work on invertebrates has included a few experiments on insects, and a microscopic examination of the heart of tarantula, polyphemus moth, and the grasshopper,

4. Ransom, Jour. of Phys., vol. 5, p. 324, 1884.

5. Brock, Zeit. f. Wiss. Zoöl., Bd. 39, 1883.

6. Foster, Pflüger's Archiv., vol. V, p. 191.

7. Darwin, Jour. of Anat. a. Phys., vol. X, part III, 1876.

8. Carlson, A. J., Amer. Jour. of Phys., vol. XV, 1906, No. II, p. 130.

but in no case did he find nerves in the heart or any connecting the heart with the central nervous system.

McClendon[9] found a nerve-cord on the dorsal side of the heart of the scorpion, and Beyne,[10] in his research on the origin of heart action, nervous or muscular, says that he found no nerve-cells in the snail's heart.

METHODS.

The most serious difficulty in connection with this research was to obtain a method by which the heart-tissue could be removed from the hard chitin and sectioned without injuring the structures.

The first method employed was to use decapitated specimens, or dorsal sections, in which the viscera were removed and the heart-tube left intact. Such specimens were placed in the fixative for the required length of time, washed and run through the necessary solutions, and embedded in paraffin. When the paraffin had hardened the outer covering was cut away, and with it the hard chitin. This method was very unsatisfactory. The tissue became brittle and dry and chipped away with the chitin, so that complete sections could not be obtained.

I finally hit upon a method that gave favorable results. After exposing the contracting heart to view in its dorsal chitin, a drop of 1 per cent. acetic acid containing methyl green was placed upon the tissue, which at once stopped contracting. As it was desired to examine this preparation under the microscope, I tried to remove a section of it from the chitin and to my surprise found that the whole delicate structure could be entirely separated from the chitin by carefully lifting one end of the soft tissue with the forceps and gently scraping next to the chitinous surface with a scalpel.

I then decapitated an animal and filled the body cavity with the 1 per cent. acetic acid and found that in a short time, three to five minutes, the whole body was so completely loosened from its encasement that, by carefully cutting the chitin along both sides and employing the scalpel, the entire body could be removed, leaving the outer shell quite transparent and entirely free from all of the body-tissue. Even the hard chitinous structures extending into the thorax were loosened from their tissues.

9. McClendon, Biological Bulletin, 1904, VIII, p. 88.

10. Beyne, J., Zeutralblatt für Phys., Bd. XIX, No. 25, 1905, p. 959.

I found that 2 per cent. formic acid would produce the same results, if left on the tissue no longer than five minutes. After having the tissues thus so well removed from the objectionable chitin, they were placed in the several fixatives. It was found, however, that the acetic acid shrank the cells—especially the so-called "ganglion-cells"—and the formic acid did not work well with some of the fixatives.

I next found that the fixatives could be put upon the tissue at once with the same results as the acids used. I cannot say that this is true for all fixatives, but I am inclined to think that it is, since its results were satisfactory for those tried, especially with the chrome-oxalic mixture, the method which I found among the best for this work.

There is one precaution, however, to be observed. The tissue should be removed from the chitin in from three to five minutes after being killed with the fixative. A longer time seems to make the tissue soft and thus impossible of removal without tearing. If left for months in a preservative such as 10 per cent. formalin it gets crumbly or brittle and the results are not satisfactory.

A great many different fixatives and stains were employed, most of which were after the direction of Hardesty,[11] Houser,[12] and Lee,[13] with some few individual variations. Over seventy different preparations were mounted.

Flemmings' fluid, so helpful for cytological purposes, proved to be of no value on the heart-tissue.

Unsatisfactory results were also obtained with picric acid, in which specimens were fixed for two or three days and then washed in alcohol; Gilson's fixed from one to two days; Pereny's fluid for eighteen hours; chrome-silver, as described by Houser; gold chlorid, according to Hardesty (p. 51), and mercuric chlorid and formalin (10 per cent.); silver nitrate, also described by Hardesty (p. 41); and even Bethes' injection method, by Hardesty (p. 43). In the latter case the sections were not well fixed and would not clear up, although the method was carefully tested. Houser reports a similar result with Bethes' method.

Most satisfactory results were obtained with 10 per cent. formalin as a fixative, and iron-hæmatoxylin as a stain; and

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11. Hardesty, Neurological Technique.

12. Houser, G. L., Jour. of Comp. Neurology, vol. XI, No. 2, 1901.

13. Lee's Vade Mecum, fifth edition.

the Nissl stain and chrome-oxalic fixative of Graf, as described by Houser. Graf used a mixture composed of 200 cc. of an 8 per cent. aqueous solution of oxalic acid, 150 cc. 95 per cent. alcohol and 150 cc. of aqueous solution of chromic acid. The tissues were fixed about six hours and then washed out with 70 per cent. alcohol, and sections made by the paraffin method.

The Nissl stain (methylen blue 3.75 grams, olive-oil soap 1.75 grams, and 1000 cc. distilled water) was poured steaming-hot over the sections for about five minutes. Differentiation was accomplished with anilin alcohol, and clearing with oil of cajeput.

The erythrosin mixture of Held, also mentioned by Houser, gave good results as a counter-stain.

Sections preserved for several months in 10 per cent. formalin were stained with the Nissl stain with good results.

Van Gehuchten's fixing fluid, according to Hardesty (p. 98), but using Nissl staining fluid and erythrosin for a counter-stain, proved to be good, especially for connective tissue.

The only fixatives that brought out the so-called "ganglion-cells," however, were 10 per cent. formalin and mercuric chlorid or formalin alone, and the chrome-oxalic fixatives. The simple 95 per cent. alcohol fixation, as used by Nissl himself, with the Nissl stain, gave good results, but the chrome-oxalic solution was the more satisfactory.

Sections through the ventral nerve-cord and the thoracic and abdominal ganglia were made with the best methods, in hopes that ganglion- and nerve-cells could be certainly identified and their structures compared with others found in the heart, but satisfactory results were not obtained with any of the many methods used. In fact, structures found in and around the ventral cord did not any more resemble nerve- or ganglion-cells, as we would expect to find them, than did those found in the heart sections. For this reason it has certainly not been proven that nerve- or ganglion-cells do not exist in the grasshopper's heart.

ANATOMY OF THE HEART.

My observations corroborate in most respects the description of the circulatory system in insects, although very little mention is made of the grasshopper. Graber[14] seems to have made a sketch of a cross-section through the heart, but it is

14. Graber, Folsom's Entomology, p. 125.

only diagrammatic. I was not able to obtain his paper. Minot[15] made a histologic study of the grasshopper but did not give much attention to the circulatory system. His paper contains quite a complete bibliography of work done on the insects prior to his publication.

As is described for most insects, I found the pulsating tube to end blindly in the last abdominal segment and the pulsations to extend forward. This was proven by exposing the heart along its whole extent, but leaving it intact in the chitin, and then placing a few drops of Ringer's solution colored with neutral red on the posterior portion. Particles of the red were taken into the heart and carried forward as far as the mesothorax. The contractions did not seem strong enough to force them any further. This experiment confirms the opinion that the blood enters the heart through lateral slits or valves. There is probably a pair of these valves for each segment, although microscopical sections did not reveal any definite valvular structures. A few sections gave evidence of folds in the tube, which were probably the valves.

Figure 1, plate XXXVII, represents the heart in position as it was usually exposed for experimentation. As will be seen, the tube itself shows very little variations in size throughout its whole extent. There is a slight enlargement at each segment, an enlargement in the metathorax, and also one in the mesothorax. In the prothorax it becomes smaller and extends as a delicate tube, quite free from surrounding tissue or pericardial cells, into the head-cavity, where it is lost under a large air-sac just back of the eyes.

No other pulsating tube can be detected in any part of the body, even by the aid of the microscope. It is very probable that this anterior tube, or aorta, empties its fluid into the body-cavity, and by means of the respiratory movements, perhaps, and the pulsating sinuses, both ventral and dorsal, the blood finds its way back to the posterior part of the body, where it again enters through the valves of the heart and is propelled forward. Owing to the extensive system of tracheal tubes and air-sacs, located all over the body, it is probable that the blood never becomes very venous, and the heart's chief function is therefore to keep this fluid in motion and the tissues well bathed with it.

That the heart contraction is not dependent upon extrinsic

15. Minot, C. S., Extracted from the second report of the U. S. Entomological Commission, 1880, p. 196.

influences for its control is shown by several experiments. As was described in my previous paper, the heart will contract many hours after being entirely isolated from all other systems. If all the blood is entirely removed from such an isolated heart (fig. 1) by means of filter-paper, the contractions soon cease. But if Ringer's solution is then placed upon the heart, in the body-cavity, the contractions will be resumed. This fluid seems to act in this respect as the animal's own blood. The heart usually contracts at the same rate throughout its whole extent, but this is not always the case. I have observed different rates in different segments.

An isolated heart may be sectioned at each abdominal segment, and if kept moist with Ringer's solution, each small segment will contract for several hours. In this case the segments do not contract in unison.

HISTOLOGICAL STRUCTURE OF THE HEART AND PERICARDIAL CELLS.

The heart, as seen in cross-section, plate XXXVII, figure 2, lies within the pericardial sinus, and on its dorsal aspect is suspended to the chitin by muscle-fibers and connective tissue. Fibers also lead off from the ventral side of its muscular coat and extend out into the fibrous tissue (*b*, fig. 2), and to the so-called alary muscles. These alary muscles are arranged in fan-shaped bundles, as is shown in figure 1. The wide part extends over the heart, to which it is attached, and the narrow part, or handle of the fan, is attached to the tergite of each segment. Some of the fibers of these muscles extend from their attachment on one side of the wall entirely over to their attachment on the opposite side, while others seem to end in the heart-muscle proper. As viewed from the ventral side, these muscles are seen to contract and expand slightly with the pulsation of the heart, but they also have a pulsation independent of the heart's contraction, and usually at a much slower rate. It is probable that these contractions help the blood to pass through into the pericardial sinus.

The muscle-fibers of the alary system are striated and contain elongated nuclei.

The muscular coat enclosing the heart-cavity is composed of two kinds of cells—one consisting of long muscle-fibers extending around the tube and out into the surrounding tissue as a sort of supporting structure (*f*, fig. 2, and *b*, fig. 7, plate

XXXVII), and the other made up of larger cells as shown in longitudinal section (*f*, fig. 3, and fig. 8). These cells often contain a network of fibers, as seen in figure 8, and also structures resembling nerve-cells (*n*).

In cross-section the heart-muscle appears to be striated, but this is probably due to shrinking of the muscular structure, thus causing the outer tissue-covering to arrange itself in folds.

On either side of the heart-tube is a tracheal tube (figs. 2 and 3, *t*), which makes connection with a spiracle in each segment.

Besides these structures, four distinct kinds of cells are to be found between the alary muscles and the chitin: First, the compact fibrous layer (*b*, fig. 2) next to the alary muscles. Numerous fibers, muscle, and perhaps nerve, extend throughout this layer. The cells are close together, and the nucleus is quite large.

The next and most numerous group of cells is the connective-tissue, or pericardial, cells, which loosely fill the cavity between the more compact ventral and dorsal groups. These cells are shown at *c*, figures 2 and 3, and again at figure 5. Some investigators call them fat-cells, but I see no reason why they should be called that. They are more or less fibrous, too, irregular in shape, vary somewhat in size, and contain a rather large nucleus with many spherical chromatin bodies. Two nuclei are often to be seen in a single cell.

Scattered throughout these cells are structures that very much resemble nerve-cells (*i*, fig. 2), but they are probably only another form of connective-tissue cells.

The most dorsal layer of tissue contains two distinct kinds of cells (fig. 2, *d* and *e*). Those again shown at figure 6 are found in the greatest abundance. They are arranged in rows (usually only one) along the dorsal wall next to the chitin.

The cytoplasm in these cells forms a network throughout the cell. The nucleus is large, with many deeply staining chromatin bodies.

Scattered among these cells, at apparently no regular intervals, are the cells, probably the same as Dogiel called ganglion-cells. These cells are shown at *e*, figure 2, and again a single cell enlarged at figure 4.

These are the cells that are not shown with most of the fixatives. The chrome-oxalic mixture and Nissl stain, or 10

per cent. formalin and iron-hæmatoxylin, show them as illustrated in figure 4. These cells more nearly resemble the ganglion-cells of the vertebrates than any other structures thus far found. They have a distinct, dark-staining nucleolus. The nucleus is quite clear. The cytoplasm is very dense throughout the whole cell.

It is very easy to call these ganglion-cells when one is especially looking for that kind of cells, and yet there is much evidence against their being of this character.

First, in only a few cases have I seen any processes resembling nerve-fibers leading from these cells. Second, they are not confined to any definite place, as one would expect to find ganglion-cells. I have noticed, however, that they are very much more numerous at the place of attachment of the alary muscles to the chitin, and if they are ganglion-cells they may control the action of these muscles as well as those of the heart.

A ventral sinus of similar structure and with similar pulsations has been described as lodging the ventral nerve chain, and these same cells are to be found in this sinus. Ransom gives this as one reason why they are not ganglion-cells, but it seems to me that it is an evidence for, rather than against, such a view. Since these ventral pulsations are similar to the dorsal, it would be expected that they were controlled by the same kind of cells.

Figure 9 is a cross-section through a thoracic ganglion. The methods used did not bring out the nerve- or ganglion-cells very satisfactorily. In fact, very few structures in the least resembling nerve-cells could be seen anywhere excepting around the edges and near the middle of the section. The large round cells scattered around the edge of the section somewhat resemble the large cells seen at figure 6, except that the nucleolus does not stand out so distinctly. In fact, the whole cell does not show a definite structure.

From the results thus far obtained I cannot therefore say that nerve- or ganglion-cells do not exist within the heart-structure of the grasshopper, and I believe they are present and need only the proper stain to prove their existence.

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SOME LABORATORY METHODS IN EMBRYOLOGY, II,

INCLUDING A DESCRIPTION OF A SIMPLE PARAFFIN-BATH AND A NEW STYLE OF SECTION-KNIFE.

BY R. G. HOSKINS.

(Contribution from the Zoölogical Laboratory, No. 185.)

One figure.

IN a previous paper* was given a summary of the technical methods used in dealing with embryological material in the laboratories of the University of Kansas. The subject of holoblastic cleavage material, however, was not treated in detail. This paper is largely an attempt to remedy that deficiency. The methods are given in some detail, as the difficulties of handling this sort of material lie mainly in the minutiæ. No attempt to assign specific credit is made; the methods are the result partly of suggestions from the literature on technique, partly of suggestions by Doctor McClung and partly the outcome of experimentation by the writer.

For illustrating holoblastic cleavages, frog and salamander eggs are used. For studying the whole eggs the latter are more satisfactory on account of their having less pigment; for sectioning they are about equally good.

Various methods of making whole mounts were tried—using both glycerin-jelly and balsam. It was found that, on account of the difficulties of sealing glycerin-jelly mounts, balsam is decidedly the more satisfactory. The eggs are first fixed in four per cent. formalin, which hardens them slightly, but leaves the gelatinous matrix that surrounds them unchanged. The removal of this envelope follows next. This is rather a baffling or decidedly an easy matter, depending upon the method used. The best way is simply to roll the eggs over

* "Some Laboratory Methods in Embryology," Kan. Univ. Sci. Bull. IV, 4.

rough bibulous paper until the envelope is left behind; if carefully done, the eggs quickly roll out onto the paper uninjured. They can then be placed directly in strong alcohol, preferably 98 per cent. This is better than using successive grades of alcohol, as it saves time, reduces the dangers of handling and causes no appreciable distortion. The eggs are then cleared in creosote or turpentine and are ready to mount. These oils are preferable to xylol as they leave the material less friable. A few drops of thick balsam are placed on a slide, and one or more eggs, after being rinsed with xylol, are laid on this and allowed to sink into it. The balsam should be thick enough to form a mass of sufficient depth entirely to submerge the eggs, as, otherwise, if any of the gelatinous matrix is left upon them, it takes up minute air-bubbles as drying proceeds. If care has been taken to select only eggs that orient themselves satisfactorily in the preserving fluid, this same orientation will be maintained in the balsam mount. This is rather an important precaution, as, without it, the eggs are likely, before the mount is dry, to take an unsatisfactory position that can not well be remedied. The eggs may be mounted either singly or in a series with about equal ease.

After the balsam has hardened enough to hold the eggs firmly *in situ*—one or two days—a protecting cover is placed upon them. An ordinary cover-glass, supported on bits of glass, can be used by putting it in place and filling in with balsam from one side. A little xylol should be run over the balsam just before the cover-glass is put in place, to avoid getting air-bubbles into the mount. Rather a more satisfactory covering, however, is a small watch-crystal, 10 or 15 mm. in diameter, the size depending upon the number of eggs on the slide. A drop of xylol is put into the crystal, which is then filled rounding full of thick balsam. Another drop or two of xylol is poured over it and any air-bubbles present removed. Then the slide holding the eggs in their balsam matrix is similarly moistened with xylol and inverted onto the watch-crystal so as to enclose the eggs. The convexity of the matrix does away with the chief difficulty of watch-crystal mounts—the tendency of the fluid to run out sidewise, thus introducing air. The mount is now ready to set aside to harden; care must be taken, however, that a good ring of balsam entirely surrounds the edge of the crystal so that air cannot be drawn in as the balsam dries.

For sectioning, the eggs should be removed from their matrices and fixed in picro-sulfuric or some other good fixative. Four per cent. formalin does not give good results except for whole mounts, but probably ten per cent. would prove more satisfactory. The extreme friability of the yolk material makes the eggs difficult to section by ordinary methods. This can be done easily, however, as follows: The eggs are cleared in turpentine, then infiltrated with paraffin melting at about 54 degrees. They are then removed from the paraffin-bath, *and the paraffin allowed to harden.* Afterwards they are placed for a short time in 62-degree paraffin, so that the superficial elements may become infiltrated with it, while the yolk material is impregnated with the softer paraffin. This leaves the eggs in sufficiently homogeneous condition to section well. The blocks should first be cooled thoroughly, and then sectioned quickly in a rather highly heated room so that only the outer part of the paraffin becomes heated enough to permit the sections to "ribbon." In this way the development of disastrous stresses due to the disparity in consistency between the various elements of the section is prevented. An electric-light bulb suspended directly above the block and near enough to warm one side of it facilitates matters by causing the paraffin to ribbon better.

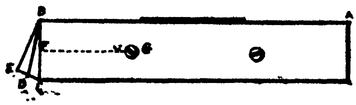
For staining the sections, either Zwaardemaker's safranin or hæm-alum and orange G. can be used, but almost any good nuclear stain will do.

Incidentally, it might be well at this point to refer to the infiltrating apparatus used. It consists only of a fifty-candle-power electric bulb suspended over the paraffin contained in an ordinary glass tumbler or Stender dish. Its advantages over the ordinary kinds of paraffin-baths are obvious. It is entirely simple and the material is always infiltrated at the lowest possible temperature—that of the barely melted paraffin of the layer just above the solid part upon which it rests. A bulb of lower candle-power can be used if a reflector is added to concentrate the heat. Only the paraffin in the upper part of the container should be melted. This can be regulated by raising or lowering the electric bulb.

Opportunity may be taken at this point to mention also a section-knife that Doctor McClung, of this department, has recently devised. Its purpose is to do away with the trouble incident to keeping an ordinary knife in good condition. It

consists of a holder for an ordinary safety-razor blade and is made as follows: Two pieces of steel are used as supports; they are in shape, in cross-section, plain wedges, as shown in the accompanying illustration. The inner faces are planed to fit each other accurately, no allowance being made for the thickness of the razor-blade. To secure sufficient rigidity the supports should be as thick as the carrier of the microtome on which the knife is to be used will permit. The two parts of the support are held together by two screws, as illustrated, the screw-heads being countersunk so as to have bearing-surfaces parallel with the inner surfaces of the supports. The dimensions of the knife described are:

A—B, 126 mm.
B—D, 22 mm.
D—C, E—D, 5 mm. F—G, 18 mm.



The apparatus has been found in practice to work quite satisfactorily for the softer tissues, but is not sufficiently rigid for the denser ones, such as skin.

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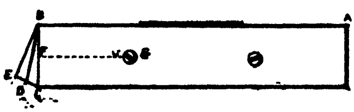

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NOTES ON SOME NORTHERN ARIZONA BIRDS.

BY ALEX WETMORE.

(Contribution from the Zoölogical Laboratory, No. 186.)

FROM February 24 to April 1, 1907, I was stationed at Williams, Ariz., a town of about 1200 inhabitants, on the main line of the Atchison, Topeka & Santa Fe coast lines. The elevation was 6700 feet, and the town itself is in a little hollow on the north slope of Bill Williams Mountain, which rose to an altitude of 10,000 feet. The whole country was of essentially volcanic origin, as numerous "cinders" (lava) and a few strongly alkaline "crater" lakes testified. At Crater Mountain, two miles northwest, part of the opening of an old volcanic cone could be traced. Directly south was a rocky canyon, called by some the Head of the Cataract, which drained the country toward the north and finally, grown deeper, joined the Grand Canyon of the Colorado river, under the more pretentious name of Cataract Canyon. The prevailing soil appeared to be a clay, usually of a reddish color, thickly strewn with loose stones, principally of quartzite, near Bill Williams Mountain.

The mountain itself rose approximately in three huge terraces, with the summit about eight miles from town. It was covered with snow all during my stay and I climbed only as far as the lower edge of the spruce belt because of this. To the east could be seen Kendricks, San Francisco, and Sitgreaves Mountains, in the order named, forming an imposing trio, with the largest in the center.

The yellow pines (*Pinus ponderosa*) abounded, with spruce occurring toward the summit of the mountain, while to the north scattered cedars and piñons could be found. The avifauna was Canadian, with transition zone species occurring in the piñons and on the open plains.

The weather, taken as a whole, was very good during my stay. It snowed at least once every week and sometimes twice, but six inches of snow lasted only a day or two and did not seriously interrupt my field-work. The days were usually as clear as possible, however, with scarcely a cloud in the sky. There was great variation of temperature between night and day, from +30 deg. Fahr. at four A. M. to +70 deg. at noon being about an average. By the end of the first week in March signs of migrational activity were noticed, and by April 1, the time of my departure, nearly all of the earlier species of birds had come.

The following notes are based on a collection of 170 specimens, representing 39 species. As there are so few of them I have given in its proper place the date when each was taken.

I wish to thank Mr. Oberholser for correcting my identification of the horned lark taken.

1. *Buteo borealis calurus* (Cass.)—WESTERN RED-TAILED HAWK. A *Buteo*, presumably this species, was heard screaming on the side of the mountain February 26. On March 11 I found a pair of these red-tails about three miles west of town, near Supai. They were rather wild, but must have picked on a location for a nest, as they always returned to one locality.

2. *Falco sparverius deserticola* Mearns.—DESERT SPARROW HAWK. Five adult males, taken on the following dates: March 13; March 21, two; March 29, two. First seen March 13, and became more and more common toward the end of my stay. One bird had a mouse of the genus *Microtus* in its talons when shot. These little hawks were very tame and heedless. One that I saw flew into a pine tree and perched out of sight on the opposite side of the bole, screaming shrilly. I circled round looking for it, but it was several minutes before I discovered the bird, as it sat crouched down on a big limb with its head towards me, looking like a twisted branch and evidently relying on its protective coloration to escape attention.

3. *Dryobates villosus hyloscopus* (Cab.)—CABANIS WOODPECKER. One male, taken March 19. Two females, taken March 2 and 8. Not very common. Were so wild that it was hard to get near them. They were found among the pines, and sometimes I would follow one nearly a mile, only to have it start out at last and fly until it was out of sight in the distance.

4. *Sphyrapicus varius nuchalis* Baird.—RED-NAPED SAPSUCKER. Two adult males, March 11 and March 29; one adult female, March 17. One of the male specimens has the red on the throat extending much farther over the black of the upper breast than the other, while in the female the chin is white and the throat only is red. First seen March 11, when one was taken near Supai. The stomach was empty, and as it was about nine A. M I think the bird had just come. Later they became fairly common. The female, shot near Rollins Lake March 17, had tapped a pine tree near an old ax-cut, and the stomach was filled with ants. The birds gave the weak *Keh-a* note of the eastern variety, but had not become very noisy yet at the time of my departure.

5. *Syphyrapicus thyroideus* (Cass.) — WILLIAMSON SAPSUCKER. One adult male, taken March 8. Only one of these birds was seen. It flew into a pine and kept so well concealed that it was some time before I could get sight of it.

6. *Melanerpes formicivorus* (Swains). — ANT-EATING WOODPECKER. Three adult males, March 8, 19 and 25. A number of these birds were seen in rather open woods on the side of Bill Williams Mountain. They invariably perched on the tops of the tallest dead trees, and flew high in the air from one point to another, quite a different habit from what I had observed in the California variety. Beside the usual *ja-cob* I heard them give a rattling note similar to that of *Melanerpes erythrocephalous*. The plumage in the birds taken is very soft and thick, and I am of the opinion from this that they had spent the winter here.

7. *Melanerpes torquatus* (Wils.) — LEWIS WOODPECKER. One adult male, March 25; two adult females, March 13. The male has red on the anterior portion of the head more extensively, but otherwise resembles the females. These birds were rather common in sheltered localities around Crater Mountain. I found them in pairs sitting out of the wind on the dead treetops. They were wary and hard to secure. The flight was direct and flapping, like that of a jay, entirely different from the free, bounding flight of most of the woodpeckers, while their long black wings gave them a crow-like appearance. I have never heard them make a noise of any kind except once, when one that I had winged gave a harsh screaming note.

8. *Otocoris alpestris leucolæma* (Coues).—PALLID HORNED

LARK. One adult male, taken March 29, has been referred to this form by Mr. H. C. Oberholser. A number were found on this date on an offshoot of the Coconino plains northeast of Williams. They were silent, and hard to find, because of their protective coloration.

9. *Cyanocitta stelleri diademata* (Bonap.)—LONG-CRESTED JAY. Five adult males, February 24, February 26; two March 8, March 13. Three adult females, March 13, 17 and 21. Common everywhere in the pines. Found in flocks, usually on the side of the mountain. They were rather wary and kept ahead of me in the woods, but when I could manage to catch up with them they seemed to rely on the thick branches of the pines for concealment. This would have been sufficient had the birds been able to remain quiet, but they were continually moving about and screaming and so exposed themselves. They began to mate before I left, and I think from their actions that a few pairs had already begun building. These jays usually kept to themselves, though I found a few of them with flocks of *Cyanocephalous cyanocephalous.*

10. *Aphelocoma woodhouseii* (Baird).—WOODHOUSE JAY. One adult male, March 13. One or two small flocks of this species were found in the piñons on Crater Mountain but were very wild. They had the same flat, rapidly given note as *Aphelocoma californica,* and reminded me of that bird in their actions. Whenever I saw them they were always out of range and slipped away through the piñons so fast that I could not get near them.

11. *Cyanocephalous cyanocephalous* (Weid.)—PIÑON JAY. Two adult males, March 29; three adult females, March 8, 13 and 29. Common in suitable localities in the piñons. Williams was about the highest point that they were found on the mountain, as they never got far away from the piñons. Until the end of my stay they were very wild, and sometimes I would follow a flock through the pines for fifteen minutes with their strange querulous notes continually sounding just ahead of me, without even catching sight of one. One female, shot March 8, contained a fully developed egg, but the greater number of the birds had just begun to pair on my departure. The last day or two they were not so wild. I found them feeding on the ground then, and when frightened they flew up only into the dead limbs of the trees to give their queer, half-laughing

notes. Even in the small series taken there is considerable variation in the depth of coloring. This may be due to age, the darkest ones being the young of the previous year, as the nesting female taken, which was presumably adult the previous year, is paler colored than any of the others.

12. *Sturnella magna hoopesi* Stone.—TEXAS MEADOWLARK. Three adult males, March 17, and March 29, two. One adult female, March 29. These birds are typical *S. magna hoopesi*, and this record extends their range, as given by Ridgway (Birds of North and Middle America, part II, p. 361), from southern Arizona to about 200 miles farther north. They were first seen March 17 and became fairly common later. I found these birds on a narrow neck of the Coconino plains, and became certain at once that they were not *Sturnella neglecta*. The song resembled that of our eastern *Sturnella magna* very closely, and was nothing like that of *S. neglecta*. These birds also had the same sputtering call-note of the eastern variety. In coloration the four specimens taken average as light as *S. neglecta* from Oklahoma, taken in January, and from western Kansas, taken in October. The black bars on the tertials and middle rectrices are separate in three specimens and nearly so in the fourth. There is no yellow on the maxillary region at all, and the yellow on the underparts is deeper than in *S. magna*, having a slight orange tinge. The female has the yellow of the under parts restricted to the median line and much obscured by the buffy tips of the feathers.

The measurements are as follows, taken in millimeters:

	Length.	Wing.	Tail.	Exposed culmen.	Tarsus.
No. 2655, male adult, March 17.......	231	120	67	31	38
No. 2715, male adult, March 29.......	228	115	66	31.5	36
No. 2716, male adult, March 29.......	228	120	71	31	36
No. 2717, female adult, March 29.....	221	109	61	30	35

13. *Carpodacus cassini* Baird.—CASSIN FINCH. Five males. adult and immature, March 11, March 19; March 31, three; five adult females, March 11, four; March 19. One immature male taken differs from the females in slightly darker olive back with darker and more sharply defined streakings above and below. Fairly common after March 11, on the side of Bill Williams Mountain. They were usually a little wild and difficult to approach. One day I found a flock of about fifty scattered through the pines on a level bench high up on the mountain, singing in chorus, as so many of the *Fringillidæ* do.

The song, a sweet warble, like that of *Carpodacus purpureus*, but softer and with not so much carrying power, fitted in well with the babblings of dozens of little brooks carrying away the melted-snow water. The ordinary call-note was a single dull note, not at all metallic. Frequently I found the birds feeding on the ground in the shelter of the low pines, in company with various sparrows.

14. *Carpodacus mexicanus frontalis* (Say).—HOUSE FINCH. One immature male, February 26. One flock of about twenty-five frequented the edge of town and had probably been there all winter. Sometimes there were pine siskins and cassin finches with them. Usually I found them feeding on the ground and they would fly up on my approach to light either in a brush-pile or on a low tree.

15. *Loxia curvirostra stricklandi* Ridgw.—MEXICAN CROSS-BILL. Seven males, adult and immature, February 26; March 2, two; March 8, two; March 17, two. Two adult females, February 26, March 17. The males are variously intermediate between the golden and the full red plumage, while one of the females is much brighter than the others, having traces of orange on the sides of the breast and the rump. Of the nine specimens before me, six have the mandible crossed to the left and three to the right. These birds were common in the pines and were evidently breeding, though no nests were found. The last of June I saw them feeding young birds near the Anita copper-mine, about forty-five miles north of Williams. They were feeding, in the spring, on the pine-cones. They were very wild and erratic in their movements, and so were hard to get. Frequently I saw them flying over, high in the air, giving their steely *kimp, kimp*. Early one frosty morning a male was found sitting in the top of a dead tree in the sun, preening his feathers. A little brook of snow-water that ran through the pines near Rollins Lake was a favorite place with them for drinking and bathing.

16. *Spinus pinus* (Wils.)—PINE SISKIN. Four males, adult and immature, February 24; February 26; and March 25, two; March 25, two adult females. There is considerable difference in definiteness of the streaks on the under parts and also in the color of the specimens. In some the colors are very clear, with sharply marked streaks on the under parts, but in others the colors, especially on the under parts, are duller, with

the streaking more indefinite and obscure. The adult males have the yellow on the primaries and rectrices very bright. Compared with specimens taken in the fall in central Wisconsin, the olive of the upper parts is darker, and below the streaks are a little longer in these skins. Measurements appear to be the same. Fairly common, in flocks ranging from a dozen to fifty. One morning I found an adult and an immature male sitting together in a bush, the former singing a simple twittering song. In flocks they are rather silent, though when startled their loud *che-a* is given. In town a flock of about thirty fed every day in a vacant lot, paying no attention to people on the sidewalks. They fed in close order, apparently heedless of danger, and when startled usually flew a few feet only. A favorite perch was a telephone-wire when they were through feeding. The latter part of June I found them feeding their young in the streets of Williams, but when I left, in April, they had shown as yet no signs of mating.

17. *Passer domesticus* (Linn).—ENGLISH SPARROW. Not noticed until the latter part of March, when a single male was seen. There were a few around Flagstaff, twenty-five miles east, and I think this one came from there. The evening before a freight had picked up two cars of stulls (timbers for the mines) at Flagstaff after dark, and had set them out at Williams. The next morning, just at daylight, I saw the sparrow sitting on one of the cars calling, and got up to within a few feet of it. It is possible that the bird had gone to roost in these stulls the night before at Flagstaff, and had been carried over in this way, though of course it could have flown the distance during the night. In June I saw a pair in the town, so that the species had evidently gained a foothold there.

18. *Poœcetes gramineus confinis* Baird.—WESTERN VESPER SPARROW. Three adult males, March 17. One adult female, March 29. Found in the open around the Crater lakes; especially common on the east side of Rollins Lake, and a number seen near a lake west of Crater Mountain. First seen March 17, and common from then on. This subspecies had the same habits as the eastern bird. The only note I heard them give was a faint *tseet*. They fed on the ground among the broken rocks and were hard to find, but when forced to flight they usually lit on a rock, so that they were easily taken. During a heavy wind it was almost impossible to make them fly.

19. *Junco hyemalis* (Linn).—SLATE-COLORED JUNCO. One adult male and one immature male, February 26 and March 25. Taken from mixed flocks of juncos.

20. *Junco mearnsi* Ridgway. — PINK-SIDED JUNCO. Two adult males, February 26 and March 13. Taken mixed in with the other forms of *Junco* on the side of the mountain.

21. *Junco annectens* Baird.—RIDGWAY JUNCO. One male adult, March 8. Ridgway (Birds of North and Middle America, pt. I) calls this "species" a hybrid, *Junco caniceps* x *Junco mearnsi*. It was taken from a flock and its identity not noticed till later. The flanks are very strongly tinged with pink, and there is a little brownish wash on the tertials and greater wing coverts. The measurements taken from the skin are as follows:

	Length.	Wing.	Tail.	Culmen.	Tarsus.
No. 2616, male adult, March 8.......	150	83	73	11	21

22. *Junco caniceps* (Woodh.)—GRAY-HEADED JUNCO. Seven adult males, February 23; March 2, three; March 4, two; March 11. One adult female, March 11. In the field this bird could not be separated from *Junco dorsalis*, and in fact it was almost impossible to name any of the species of *Junco* present here, unless they were in the hand. When I first came these birds were found only in the shelter of the low pines, but as the migration began they became common everywhere.

23. *Junco dorsalis* (Henry). — RED-BACKED JUNCO. Nine adult males, February 23, March 2; March 8; March 11; March 19, two; March 21, three. One adult female, March 11. This species, together with *Junco caniceps*, formed the bulk of the juncos seen. The two species were mixed together, and examples of the others were also found in the same flocks, so that identification without the gun was impossible. When I first arrived there were only a few present, and I found them roosting in the low pines on the side of the mountain. After the first week in March they became more common, and were scattered in small flocks all up and down the mountainside, and, as they became more numerous, also spread to favorable situations on the level. When disturbed on the mountain, they flew up into the trees with the usual junco call-notes, and moved rapidly along up the slopes. They usually came back after a few minutes, seeking a lower level. On cold, windy days, they fed in the shelter of numerous deadfalls, from which it was almost impossible to flush them. *Junco dorsalis* gave a

simple twittering song with either three, four, or five notes, like *tsee, tsee, tsee, tsee*. This song was given either from an exposed perch or from the shelter of a piñon, in which it was difficult to find the bird. The last *Junco caniceps* was taken March 11, and I do not think many remained to breed. *Junco dorsalis* was found commonly after this, the last one being taken March 21, but what I took to be this species was seen till the end of my stay. They were then distributed all through the deadfalls on the mountain, and were apparently preparing to breed.

24. *Junco oregonus shufeldti* (Coale).—SHUFELDT JUNCO. Six adult males, February 26, March 2, two; March 4, 11 and 13. These juncos had the habits of the other species, but could be distinguished in the field by their black heads. There were a few present on my arrival, but none were taken after March 13, and I think they were about all gone then.

25. *Pipilo maculatus megalonyx* (Baird).—SPURRED TOWHEE. One adult male, March 8; one adult female, March 13. First seen March 8, but was common by the middle of March. They frequented the brush-covered hillsides, mounting to the tops of the branches to sing, but when I appeared dropped to the ground and ran off into cover. Frequently I hunted for more than half an hour without getting more than a glimpse of one.

26. *Tachycineta thassalina lepida* (Mearns). — NORTHERN VIOLET-GREEN SWALLOW. Five adult females, March 29. On this day I found a flock of about twenty of these birds in a wash between two hills northeast. They were feeding on the wing, calling *chu, chu* in a peculiar tone. When tired they rested on the dead limbs of the trees, but were soon flying around again. All those taken were females, but they were playing in the air as though mating.

27. *Lanius ludovicianus excubitorides* (Swains).—WHITE-RUMPED SHRIKE. One adult male taken, March 25. This bird was shot along the railroad-track, and was the only one seen. It is a well-marked specimen of *L. ludovicianus excubitorides*, and resembles others from Kansas and Wyoming.

28. *Oroscoptes montanus* (Towns.)—SAGE THRASHER. One adult male, March 31. One found skulking in the bushes near the foot of the mountain-slope.

29. *Salpinctes obsoletus* (Say).—ROCK WREN. Four adult

males, March 21; three March 29. First seen March 21 and afterward common. In June I found a nest containing four young, built underneath a stone in the canyon south of town. This species was found on rough, rocky ground, usually on the side of some knoll. They sang a great deal, and the song resembled that of a thrasher more than that of a wren. It consisted of separate notes, each one repeated three or four times, and then, after a pause, a repetition of a different one. The birds were rather hard to follow, though they kept bobbing up ahead of me everywhere. They were very nervous, and when sitting on a rock watching me kept jerking the body up and down.

30. *Catherpes mexicanus polioptilus* Oberholser.—INTERMEDIATE CANYON WREN. One male adult, March 21; one female adult, March 4. *Catherpes mexicanus polioptilus* from Arizona is, according to Ridgway, intermediate between *C. mexicanus conspersus* and *C. mexicanus mexicanus.* The two taken are almost identical in coloration with a specimen of *C. mexicanus punctulatus* from Summit, Cal., though the female is a trifle paler, and because of this I have referred them to this variety, though *C. mexicanus conspersus* should also occur here. These birds were seen in the canyon south of town, and were fairly common, but from their habits hard to find. They frequented broken rock and brush-piles, and would bob out for an instant to scold and then disappear. It was impossible to follow them, as I could never tell where they were coming up. They were usually found in pairs. Their song was a clear whistling note, repeated in a falling scale, and is one of the best that I know. It had great carrying power, and I frequently heard them singing in the morning on the mountain above town, a distance of a quarter of a mile or more. Sometimes the birds would mount into the top of a pine tree and sing for half an hour, but usually they chose some sheer rock-face in the canyon.

31. *Certhia familiaris montana* Ridgw.—ROCKY MOUNTAIN CREEPER. One adult male, March 8. This one bird, taken early one morning on Crater Mountain, was the only one seen. It came working rather rapidly down the side hill while I was watching a pair of gray titmice.

32. *Sitta carolinensis nelsoni* Mearns.—ROCKY MOUNTAIN NUTHATCH. Five adult males, February 26, March 2, 4. 11,

13; five adult females, February 26; March 4; three, March 13. Common everywhere in the timber. These birds had the same habits and notes as the eastern variety. I shot a female one day which hung in a tree, and a male came bustling around with spread wings and tail, and pecked and pulled at it until it fell to the ground. He seemed more curious than anything else, and not at all alarmed.

33. *Sitta pygmea* Vig. — PYGMY NUTHATCH. Nine adult males, February 23, March 4, 13, 19, 21; five adult females, February 23, 24, March 2, 13 and 21. This was the most common bird of the pines and was usually found in small flocks. They were very active, crawling up and down the tree-trunks or hunting through the limbs in regular warbler style, giving their soft, rather peevish notes continually. They frequently lit on a dead limb just above my head and scolded me vigorously. When the first warm weather came they began to mate, and paraded around in true nuthatch style with spread wings and tail.

34. *Bæolophus inornatus griseus* Ridgw.—GRAY TITMOUSE. One adult female, taken March 8. Seen only on this one day, when I found a pair by their harsh scolding notes on the side of Crater Mountain. The male gave a clear whistled *pete, pete, pete,* like that of *Bæolophus bicolor,* but having only one syllable instead of two. They were working rapidly through the brush, and when one was shot the other disappeared.

35. *Penthestes gambeli* Ridgw. — MOUNTAIN CHICKADEE. Six adult males, February 26; two, March 2, 8, 21 and 25. Four adult females, February 26, March 8, 11 and 17. Common. This species had the same habits and was found in the same localities as *Penthestes atricapillus* frequents in the east. The notes were harsher, like those given by the young of the eastern bird in July and August. I also heard them give a clear whistled *Phœ-be* with the last note sometimes repeated twice. They were very tame and appeared to pay no attention to me at all.

36. *Psaltriparus plumbeus* Baird. — LEAD-COLORED BUSH-BIT. Four adult males, March 25. Two adult females, March 25. One flock of about fifteen seen on Crater Mountain, feeding rapidly through the bushes. They were very quick and active, searching every nick of a limb. I heard them give three call-notes, two of them low and weak, like *tsit, tsit, tsee, tsee,*

and another louder, *tseeree*. The first one was kept up continually. They made a little disturbance over a little wounded bird, but by the time I had secured it they were all gone and I did not see them again. This species seems to be indistinguishable from those females of *Psaltriparus melanotis lloydi*, which lack the black on the head, but as the adult males of *P. plumbeus* were taken I have referred all the specimens to this form.

37. *Regulus calendula* (Linn).—RUBY-CROWNED KINGLET. Three adult males, March 19; two, March 25. A few of these were found during March. The last of June I heard a male singing in the spruces just below the summit of Bill Williams Mountain, at an elevation of 10,000 feet.

38. *Merula migratoria propinqua* Ridgw.—WESTERN ROBIN. Three adult males, March 11; two, March 21. Two adult females, March 11 and 21. The first ones seen were in a small flock in the pines near Supai. Later they became common, and were found in considerable numbers on a plateau south of town. Here they were rather wild, and when frightened usually lit in the numerous deadfalls.

39. *Sialia mexicana bairdii* Ridgw.—CHESTNUT-BACKED BLUEBIRD. Three adult males, March 2, 19 and 21; two adult females, March 8 and 17. These birds were first seen March 2, but were common a week later. They frequented the cut-over pine lands, where the numerous stubs furnished them perches. The only note I heard them give was a low *tur-wee*, like the fall note of *Sialia sialis*.

40. *Sialia arctica* Swains.—ARCTIC BLUEBIRD. One adult male, March 17. A few birds of this species were found in the same localities as the preceding one. A favorite place was near the shore of one of the numerous Crater lakes, and some of them were found in the town itself.

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SOUTH AMERICAN ARCHEOLOGICAL NOTES.

By H. T. MARTIN.

(Contribution from the Zoölogical Laboratory, No. 187.)

Plates XXXVIII to XL; four text figures.

IN the spring of 1903, while on a fossil-hunting expedition in Patagonia, South America, I accidentally discovered a very unique form of human skull in a canyon close to camp. At the time of the find nothing could be seen of more than passing interest in the bones, owing to their fragmentary condition, but recently, upon mending the broken parts, I was surprised at the unusual shape and contour of the skull. The exact locality of the find is at the mouth of a canyon on the estancia of Mr. H. S. Felton, at Killik Aike Norte, on the Rio Gallegos, about half a mile below his house, and 100 yards from the river bank into which the canyon empties. The place is shown in the photograph on plate XXXVIII, where the small cross can be seen, to the right and just beyond the camp. The most plausible explanation for its presence here appears to consider that it had been washed down from its original resting-place on the adjacent high hills which occur on either side of the canyon's edge for a distance of two or three miles inland.

Although very careful search was made, no other portions of the skeleton could be found at this point. From the nature of the surroundings, and the condition of the skull when found, there does not appear to be any possibility of determining its geological age, but after careful study and comparison there appears not the least doubt that it represents a race of people now extinct in that part of Patagonia.

The skull when found was embedded in the silty debris and wash from the hills, with its palatine surface uppermost. Only a small portion of one side of the maxilla was found, which con-

tained portions of two molars, and unfortunately the contact between the piece of jaw and skull is broken away.

By referring to plate XXXIX, figures 1 and 2, the observer will see that the skull is of a decidedly hyperbrachycephalic type, being nearly as broad as long. The whole of the frontal region is very low and flat. The frontal eminence is made to appear more prominent by the presence of a slight, almost flat, depression, which occurs between the supercillary ridge and the frontal eminence. The temporal ridge is sharp and rather prominent, and as it extends backwards appears to take more of an upward trend, rather than a downward curve as is usual when it reaches the region of the parietal, thereby giving the frontal bone a more angular appearance.

By referring to plate XXXIX, figure 2, it will be seen that the parietal protuberances are very pronounced. The temporal fossa are deeper than is usual.

From the front the malars appear square, much resembling those of the Esquimaux. The supercillary ridge is very high. The superior border of the orbital arches is straight, and shows very little rounding to form the orbital apertures, but turns at a very sharp angle at both ends, making the upper portion of the orifice almost square. The glenoid fossa is rather shallow, but very broad. The following measurements have been made:

Antero-posterior diameter, 15.7 mm.

Transverse diameter, 15 mm.

Top of cranium to auditory fossa, 12.3 mm.

Cephalic index, 95.54 mm.

Nowhere does the skull show any deformation by artificial means.

By way of comparison with the specimen just described, it has been thought advisable to give a reproduction of another very fine skull and lower jaws, also found by the writer in the Argentine Republic, at the port of San Blas, in the Rio Negro territory, about 600 miles south of Buenos Ayres. This specimen shows a very marked difference from the one previously described, and, judged not only by its proportions and shape but by the excellent examples of pottery and arrow-heads found associated with it, must have been of a race far more advanced than the Killik Aike specimen from Patagonia.

The skull shown on plate XXXVIII, figure 1, although having a rather low, slightly receding forehead, taken alto-

gether is very well proportioned, and would average as well as most of our North American Indian skulls in point of development. The triturating surfaces of the teeth show an abnormal amount of wear for an individual the age that one would judge this to be. This is owing, no doubt, to the large amount of grit found in some of the food used, such as shell-fish, and fish cast upon the shore, together with the tough meat of the guanaco, which must have constituted their principal food. A good view is shown of the sand-hill blowouts in figure 1. The

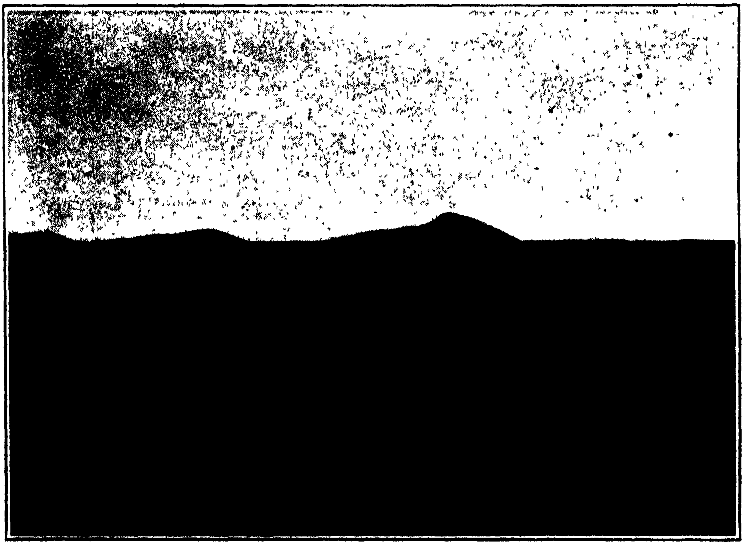

FIG. 1. View showing burial ground in sandhills at San Blas where pottery and skull No. 1 was found.

exact spot where the specimen was found is marked by the small cross. The ever-moving sand here offers an excellent opportunity to find good skeletons, quite a number having been discovered here.

Plate XL, figures 1 to 10, show some photographs of relics found associated with the San Blas specimen. It is interesting to note that nearly all of the pottery is of the incised variety, made by a process much practiced by the old Pueblo Indians, namely, of indenting by a notched piece of wood or bone. Several of the pieces show much skill in their manufacture, as well as fine taste in the decorations. The design on No. 1, the largest piece in the collection, a portion of a bowl probably ten inches in diameter, is all incised work. The pattern appears to

have been composed of four shallow horizontal impressions three-fourths of an inch apart and one-fourth of an inch wide, indented every eighth of an inch by perpendicular incisions. The three-fourths of an inch space between the incised bands is decorated by a zigzag row of small holes pressed in with a small, round-pointed tool, held at an angle of seventy-five degrees (see text, figure 2). Beneath this is a two-inch square

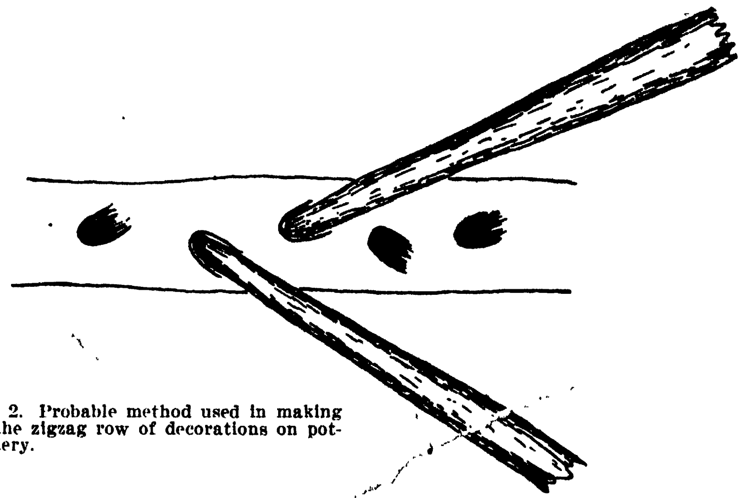

FIG. 2. Probable method used in making the zigzag row of decorations on pottery.

checkerboard design surrounded by the quarter-inch wide pattern described above. Adjoining this is a small triangular-shaped decoration of indentations, then a diamond-shaped checkered pattern, in size and design similar to the square.

Nos. 2, 3 and 4 are of simple design. Nos. 3 and 4 were probably incised with the finger nails. The pattern on No. 5 is made with a two-pronged incisor. On No. 6 are two rows of indentations different in shape from any of the others. These are crotchet-shaped impressions, and look as though made with the proximal end of a small fish rib. No. 10 shows the most elaborate decoration, apparently made chiefly with a four-notched tool, with a decoration on the inside of the rim as well. All of the pottery shows an advanced stage in the ceramic and decorative arts. The arrow-points shown are all well made. About fifteen were found close to the grave along with the pottery. No painted pottery was found, and no boleadores.

The pipe shown in the text, figures 3 and 4, is the only one the writer heard of being found anywhere along the Patagonian coast. This was presented to him by Mr. John Rudd, at

Cape Fairweather, and was found by him on his estancia about five miles above the point of Cape Fairweather, on the Rio Gallegos.

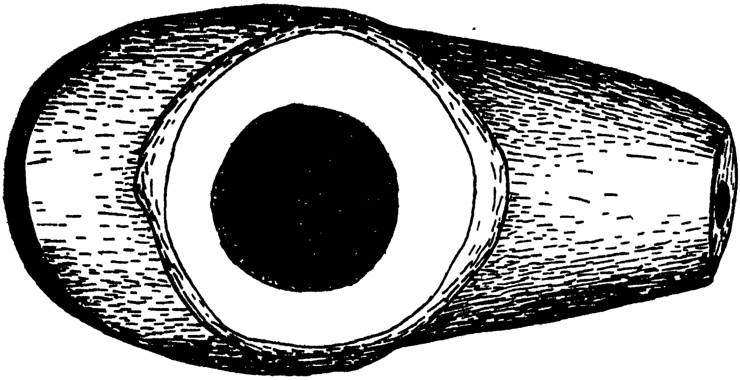

FIG. 3. Upper view of pipe found on the Rudd Estancia.

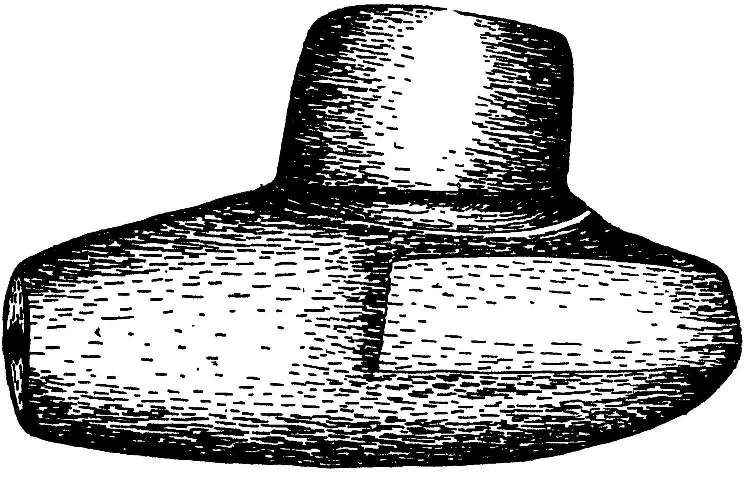

FIG. 4. Side view of same pipe.

At about a dozen other points of call along the coast a goodly number of arrow-heads and boleadores were found, generally associated with the shell heaps or kitchen-middens along the coast. At Port Deseado one of these heaps was excavated to a depth of over three feet without finding bottom. It is composed of limpet shells and is twenty-five yards long by fifteen wide.

On plate XXXI some very fine examples of boleadores are shown. These are of a pattern now obsolete, having been sup-

planted by the rawhide-covered ones now used. Nos. 1 and 2 are made of heavy granite, No. 3 of a hard sandstone. Usually two of these are used fastened together by twisted rawhide strips, about six feet long, firmly secured into the grooves, and form the bolas so much used formerly by the Gaucho to catch the ostrich and guanaco with. These specimens were presented to the writer by Mr. H. S. Felton, of Killik Aike, and were found by him on his estancia.

The voyage south from Bahia Blanca, territory of Buenos Ayres, to Gallegos, Patagonia, on the coasting steamer Chubut, was an interesting as well as instructive one. Nearly the whole distance the vessel was within sight of land, usually not over two miles away, and called at ten or twelve of the small ports to discharge cargo. By the kindness of the captain the writer was allowed to go ashore on the steam launch, which enabled him to gather at all the points visited a small collection of Indian relics. These are not at all hard to find around the old shell heaps which abound along the rocky portions of the coast. At Cabo Blanco one bank of the small bayou we entered is composed for 150 yards or more of shells, bones, and sand, the remains of an old kitchen-midden. By caving this down a number of fine arrows, scrapers and spear-points were found.

There is not the least doubt that by a careful, systematic examination of the whole region, a very extensive and valuable archeological collection could be made. Comparing the small amount of material the writer was able to secure at each port going south from Bahia Blanca, that from San Blas shows the most advance towards civilization, while further south the weapons appear more crude.

PLATE X.

Caudal view of pectoral girdle of *Xiphactinus, ca.* ½. This specimen shows the halves of the girdle in their normal relations, as it does also the individual bones. The extent of apposition between the halves, and the articulations for the fin-rays, appear clearly.

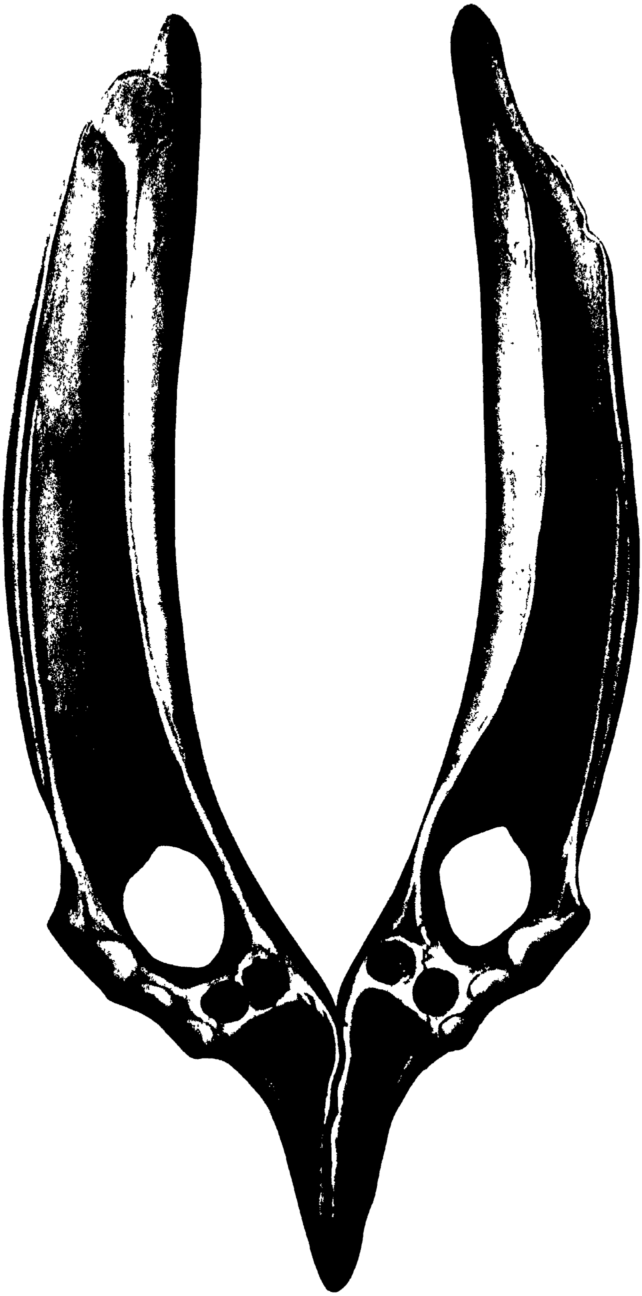

PLATE XI.

Reconstruction of the left half of the pectoral girdle of *Xiphactinus*, *ca.* ½. External view showing the extent and relations of the elements. All parts of the girdle are represented in specimens studied and the figure is merely a composite.

PLATE XII.

From a photograph of the restoration of *Xiphactinus* in the museum of the University of Kansas. This is a composite of several specimens, the only parts in plaster being the ends of the pectoral fin-rays, part of the ribs, and portions of the girdles. The restored bones are modeled from specimens.

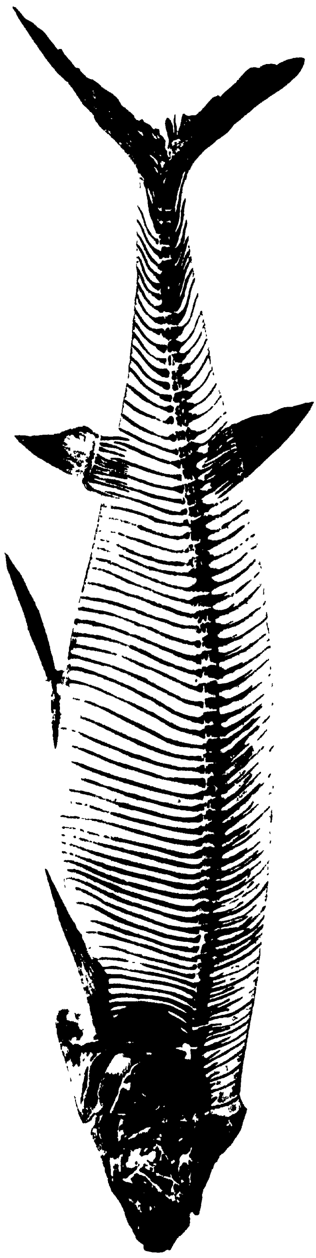

PLATE XIII.

The caudal fin of *Protosphyræna,* showing the urostyle, the fin-rays, and the ossified neural and hæmal arches. The absence of ossified centra is apparent.

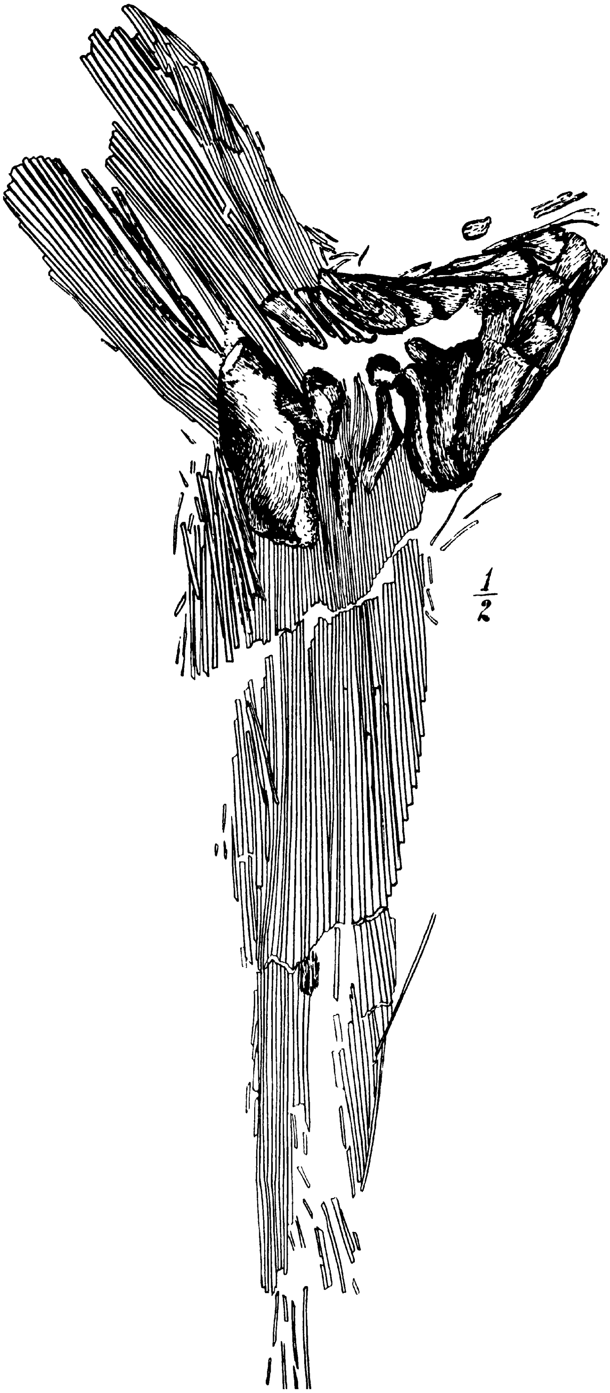

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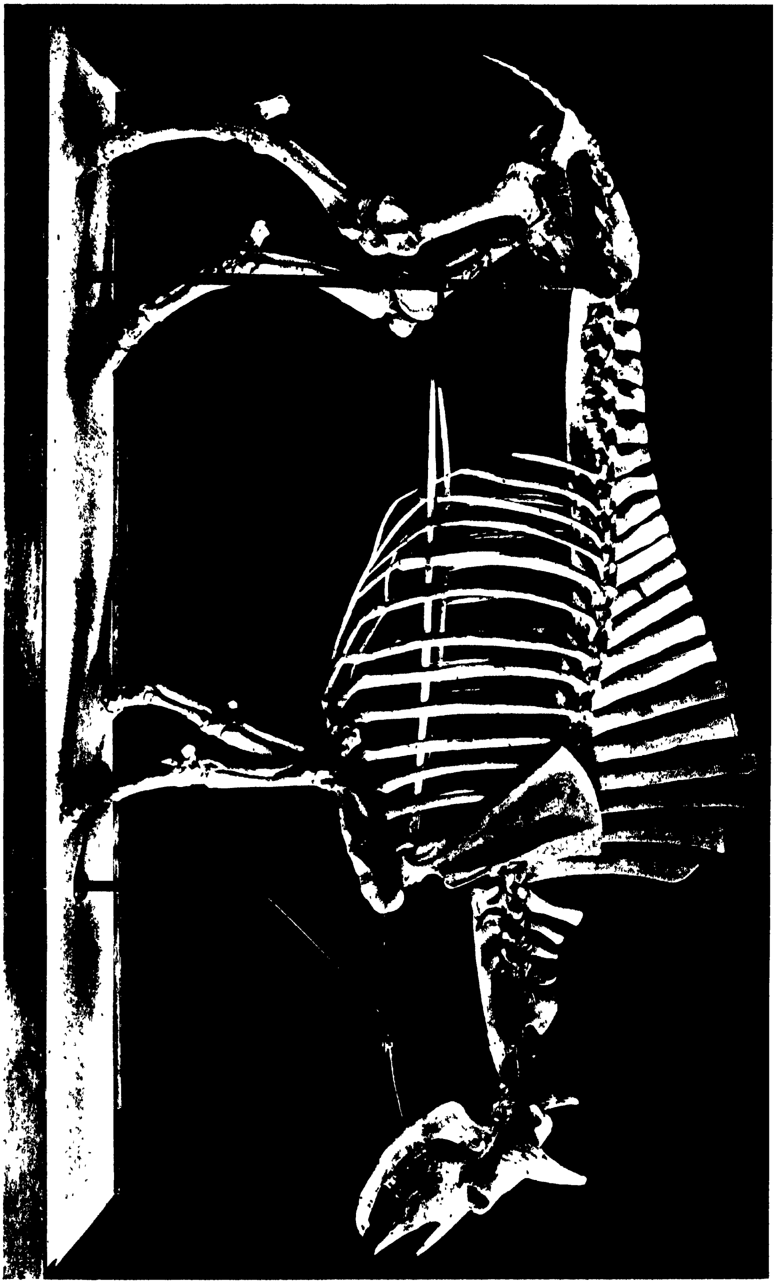
Plate XIV shows the restoration of the skeleton of *Bison occidentalis.*



EXPLANATION OF PLATE XV.

The original *camera lucida* drawings are at a magnification of 3000 diameters, and appear here at 2000. The optical equipment with which the preparations were studied consists of an apochromatic objective of 2 mm. focus and 1.40 N. A., and compensating oculars. The light of the Welsbach mantle was delivered to the objective through a Watson oil-immersion condenser of 1.30 N. A.

FIG. 1.—Telophase of secondary spermatogonium, showing the ends of the divided accessory chromosome almost in contact.

FIG. 2.—Telophase of similar cell, showing the accessory chromosome *en face*.

FIG. 3.—Same stage as figure 2.

FIG. 4.—Same as figure 2, but with the halves of the accessory chromosome more separated.

FIG. 5.—Various forms of the accessory chromosome in the prophase of the first spermatocyte. Those represented at *a, b, c,* were fixed in Flemming's fluid and stained in iron-hæmatoxylin; the remaining ones were fixed in Hermann's fluid and stained with safranin-gentian violet. The latter combination causes the elements to appear larger than the former. Variations in the form of the accessory chromosome, at about the same stage, are shown at *d, e, f, g, h*. The elements shown at *i, j, k, l, m, n,* are of later stage. Chromosomes *m* and *n* are from the same cyst, the former being a lateral view, the latter *en face*.

FIG. 6.—Polar view of a metaphase of the first spermatocyte, showing the sixteen ordinary chromosomes and the accessory chromosome beneath.

FIG. 7.—A slightly later stage than that represented in figure 6. No accessory chromosome shown.

FIG. 8.—Polar view of the first spermatocyte metaphase, showing the sixteen ordinary chromosomes.

FIG. 9.—Similar to figure 8.

FIG. 10.—Lateral view of a first spermatocyte metaphase, showing a few of the chromosomes. The one in the form of a ring lies in the plane of the spindle axis.

FIG. 11.—Same stage as represented in figure 10, but showing the accessory chromosome at one pole of the spindle.

FIG. 12.—Telophase of the first spermatocyte, showing the accessory chromosome in only one daughter-cell. 12*a* and 12*b* are views of the accessory chromosome in the same stage but with different degrees of chromatid separation.

FIG. 13.—Polar view of second spermatocyte metaphase in which the accessory chromosome is present.

FIG. 14.—Similar to the cell shown in figure 13.

FIG. 15.—Polar view of second spermatocyte without an accessory chromosome.

FIG. 16.—Lateral view of second spermatocyte with an accessory chromosome.

FIG. 17.—Mid-anaphase of second spermatocyte, showing separation of halves of the accessory chromosome.

FIG. 18.—Similar to figure 17.

FIG. 19.—Telophase of second spermatocyte, showing presence of the accessory chromosome in daughter-cells.

FIG. 20.—Telophase of second spermatocyte without the accessory chromosome.

FIG. 21.—Somatic cell in anaphase showing division of the accessory chromosome.

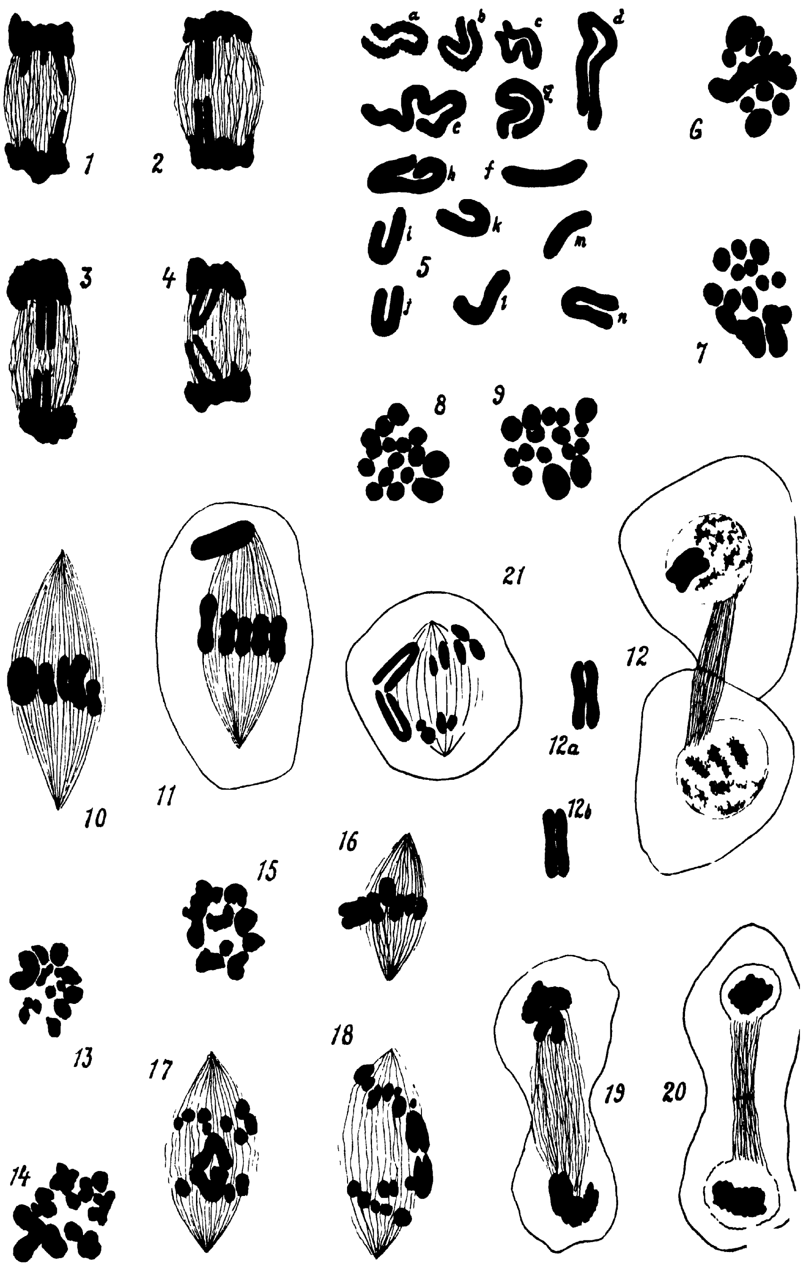

1
2
3
4
5
6
7
8
9
10
11
12
12a
12b
13
14
15
16
17
18
19
20
21

PLATE XVI.

Drawings made at a magnification of 2250. In reproduction this has been reduced to 1800 diameters.

FIG. 1.—Spermatogonium, showing twenty-three chromosomes. 12, the largest chromosome of the complex; 1, the smallest; 9, a chromosome showing the longitudinal split.

FIG. 2.—Prophase showing the accessory smooth in outline and darkly staining; 4, a chromosome exhibiting the true tetrad character; 12, the largest chromosome.

FIGS. 3A and 3B.—A single cell showing the full number of chromosomes in a first spermatocyte metaphase in lateral view.

FIGS. 5, 6, 7.—Polar views of first spermatocytes, showing the occurrence of the single ring.

FIG. 8.—Prophase. Chromosome 12 in the form of a cross.

FIG. 9.—Polar view of the first spermatocyte, showing three rings.

FIGS. 10A and 10B.—First spermatocyte metaphase, with the chromosomes numbered in the order of their size: No. 10, the ring in profile; No. 6, the accessory.

FIG. 11.—Early anaphase of the second spermatocyte, showing the separation of paternal and maternal elements.

FIG. 12.—The chromosome complex of a first spermatocyte, showing the graduated series of chromosomes.

FIG. 13.—A polar view of the second spermatocyte, with eleven chromosomes. The accessory is absent.

FIG. 14.—A polar view of the second spermatocyte, showing the full number of chromosomes.

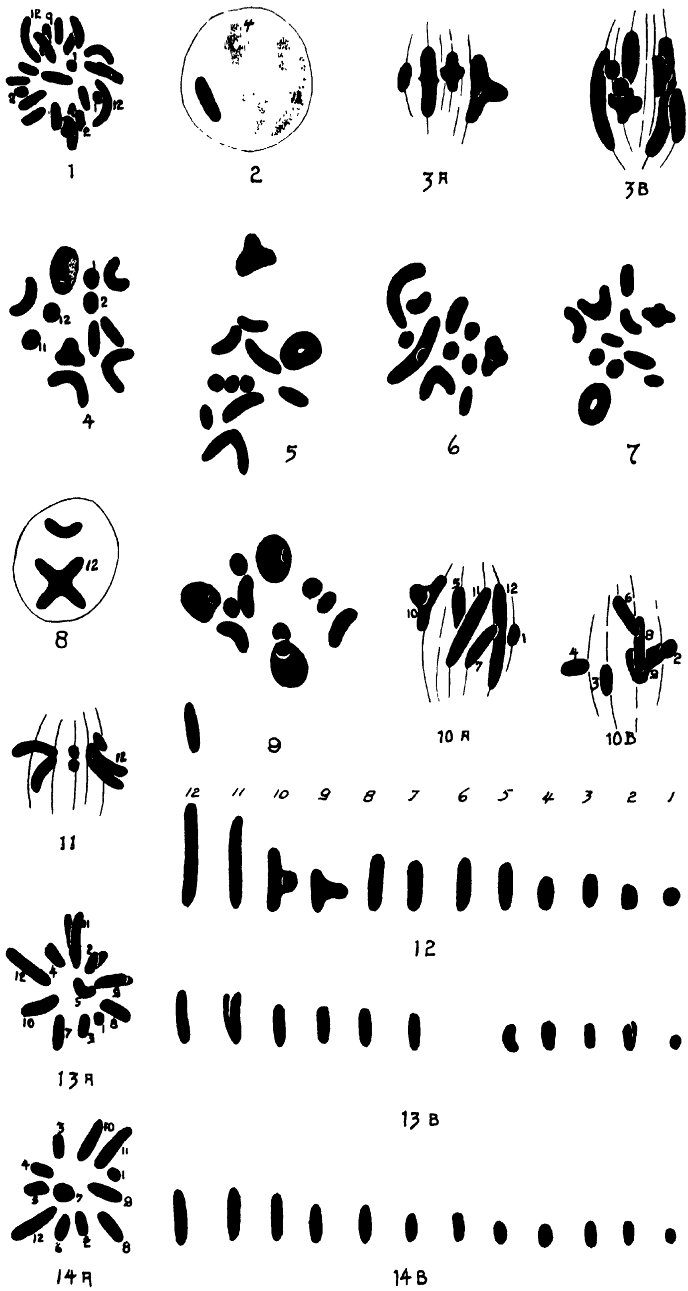
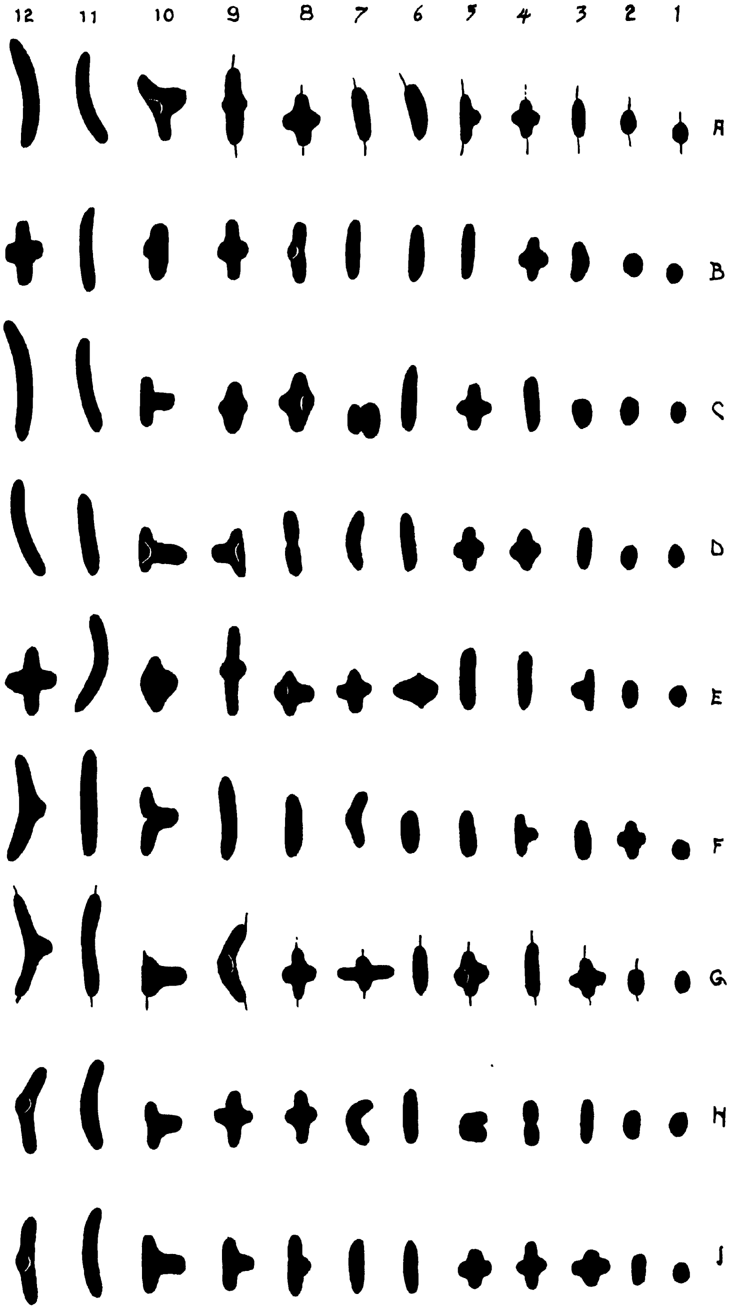

1
2
3A
3B
4
5
6
7
8
9
10A
10B
11
12
13A
13B
14A
14B

PLATE XVII.

The chromosomes of nine first spermatocytes, as seen from a lateral view of the metaphase.


12 11 10 9 8 7 6 5 4 3 2 1
A
B
C
D
E
F
G
H
J

EXPLANATION OF PLATES XVIII, XIX, XX.

All drawings were made by the author with the aid of an Abbe camera lucida, and are reproduced here at a magnification of about 1895 diameters. They are numbered as nearly as possible in the order of their development. Figures 7, 8 and 9 are the only exceptions. They represent the earliest cells that were studied, and have been placed with the later spermatocyte stages merely for convenience. Figures 1-6 and 30-46 are from cells stained with iron-hæmatoxylin and figures 7-29 from those stained with Flemming's tricolor.

FIGS. 1-6.—Spermatogonia, polar views of the metaphase. Figures 1-4 are from a single individual and 5 and 6 from two others. There are twenty-three chromosomes in each cell. The larger of them lie in the outside portion of the plate and the smaller ones nearer the center. The chromosomes are usually split (figs. 1, 2 and 6) and the halves ready to go to the poles. The separation of the halves begins at the inner end of the chromosome (fig. 6).

FIG. 7.—Early secondary spermatogonium. *X*, Accessory chromosome in its vesicle. *N*, Nucleoli, weakly stained but homogeneous.

FIG. 8.—Spermatogonium, late telophase, within a cyst of about twenty cells. *X*, Accessory, its vesicle well shown. *N*, Nucleoli stained with safranin.

FIG. 9.—Another cell from the same cyst. Accessory seen in cross-section within its vesicle; other chromosomes in cross-section also.

FIGS. 10-15.—Different stages from one follicle, not long after the last spermatogonial division.

FIG. 10.—Spermatogonium, telophase just after the last division. Cells of this stage are deeply stained. The nucleus is at its smallest volume here. The ordinary chromosomes begin to loosen up. The accessory remains condensed. The occurrence of two nucleoli in each cell seems to be quite general for the cyst.

FIG. 11.—Telophase later than the above; in a neighboring cyst. The chromatin is well diffused. *N*, *N*, Two faintly stained irregular nucleolar bodies; nucleus still small. *K*, Karyosome, probably.

FIGS. 12, 13, 14, 15.—Spermatocytes, growth period. All from same cyst. Accessory much condensed and massed into an irregular lump, still clinging to the nuclear wall. Two nucleoli present in each cell, stained with safranin like the accessory, sometimes differing slightly in size. In figures 14 and 15 they lie in close contact, possibly uniting. In the cells at the proximal end of this follicle there is but a single nucleolar body besides the accessory present. This body is about equal in volume to the two nucleoli, such as in figures 14 or 15. *K*, Mass of chromatin, probably a tardy loosening up of a chromosome.

FIGS. 16-22.—Spermatocytes, growth period following the above. All from one follicle.

FIG. 16.—Accessory and nucleolus shown. But one of the latter present. It takes the safranin stain like the accessory. Every cell in this cyst has but one of these nucleoli. Sometimes they show a tendency to lose the safranin color and appear dark purple. Accessory is larger than the nucleolus and happens in this case to lie against that part of the nuclear wall which is uppermost; but nevertheless it is in contact with the wall.

FIG. 17.—From the same cyst as above. Accessory is vacuolated, as is quite frequently the case. Nucleolus and accessory are at almost opposite sides of the nucleus.

FIG. 18.—From a neighboring cyst but at same stage as figures 16 and 17. Shows condition of ordinary chromatin in figures 16-19. Nucleolus and accessory lie close together but are separate. Nucleolus is homogeneous but not nearly so dense as accessory. *t*, A tetrad beginning to show the splitting of the thread, the longitudinal division. *p*, A plasmasome, not found in every cell.

FIG. 19.—From same cyst as figure 18. *t*, Possibly the end of a tetrad; stained with safranin. It seems not to be typical for all the cells of the cyst, for no others were found in the cyst showing this second body so prominent or so deeply stained.

FIG. 20.—Shows extreme looseness of the accessory. It is spread out upon the inner side of the upper part of the nuclear membrane. The nucleolus, besides becoming very irregular, is losing its staining power.

FIGS. 21, 22.—Slightly later stage than any of the preceding. The nucleoli are stained purple instead of red. Many others of this cyst have lost their stain. Some, however, still remain red. The nucleoli appear to be still homogeneous. The small dark bodies present are possibly small globules of chromatin already condensed. One accessory is vacuolated.

FIG. 23.—Accessory shows indications of forming a spireme.

FIG. 24.—Accessory is farther advanced. The nucleolus has lost its safranin-staining ability. *t*, A tetrad that is in advance of its fellows. The proximal ends are much condensed and stain safranin.

FIG. 25.—Shows the spireme condition of four other accessories in the same cyst from which figure 24 was taken. No indication of a special bending in the middle. It is merely an irregular coil. The diameter is very small and the length correspondingly great.

FIG. 26.—A later condition. The accessory is shortened and its diameter correspondingly increased. Five tetrads shown. *XX*, Parts of the tetrad to which the fibers from opposite poles of the spindle will be attached. Nucleolus entirely yellow or colorless but homogeneous. A count of the chromosomes at this stage shows the full number twelve, plus the nucleolus. It is therefore safe to say that the nucleolus is not a chromosome. Another evidence of its nucleolar origin is the fact that it degenerates and loses its staining ability. This takes place about the time that the chromatin is being contracted into the form of chromosomes. Clear spaces appear in the nucleus between the chromosomes at this time. The nuclear wall is still intact. In general the follicle is lightly stained as compared with other follicles and the nucleoli are rather inconspicuous in the cells at all stages.

FIG. 27.—Accessories from other cells in the same cyst as figure 26. All at the same stage.

FIG. 28.—Still later stages, showing the gradual shortening and thickening and the final straight or rod form. No indication of bivalency.

FIG. 29.—Various shapes seen among the ordinary chromosomes in the last prophase. All belong to the same type, that of the cross (*a*), and are modifications of it. *XX*, Places of attachment for the spindle fibers from opposite poles. They indicate the "proximal" end, or part, of the chromosome, the place where the members of the spermatogonial pair always come in contact. They also mark the ends of the transverse axis of the cross. A line drawn through this axis would divide the chromosome reductionally, through the opposite axis longitudinally. It is divided longitudinally the first time and reductionally in the second division. The ends of the longitudinal axis may be bent over toward each other and brought in contact, forming the rings (*f*, *i*) or the figure of 8 (*g*). If not brought in contact the semiclosed ring (*e*) or kidney and bent-rod forms may result. *a*, Cross, simple type form. *b*, Ring. *c*, Cross, ends of longi-axis bent towards each other. *d*, Another view of same. *e*, Semiclosed ring. *f*, Ring. *g*, Ring twisted in form of figure 8. *h*, Another cross. *i*, Ring greatly pulled out into transverse axis. *j*, Shows cross form among the smallest chromosomes of the complex.

FIG. 30.—Polar view of first spermatocyte metaphase. Plate viewed at an angle of 25 degrees from the perpendicular. Twelve chromosomes present, all visible in one section. Chromosomes No. 3 and 5 displaced slightly outward for convenience in drawing.

FIG. 31.—*Idem*, from same animal as above. Twelve chromosomes in their exact position. The whole eleven ordinary chromosomes may be seen at one focus. The accessory is nearer the upper pole and hence not in the same focus as the eleven.

FIG. 32.—*Idem*. Chromosomes farther advanced in mitosis than in figures 30, 31 and 33.

FIG. 33.—All in exact position except No. 7, which lay partially over No. 8. Note the smaller chromosomes in the center and the larger ones in the outer portion of the plate. The accessory is traveling toward the farther pole.

FIG. 34.—A fragment of a cell. Lateral view of the metaphase, showing position of the accessory at periphery of the cell-plate. One end only has a spindle fiber attached. *XX*, Points on ordinary tetrads where spindle fibers are attached.

FIG. 35.—Another fragmentary cell, showing the same conditions.

FIG. 36.—*Idem*.

FIG. 37.—Metaphase, eleven chromosomes dividing. The accessory is seen going off to one pole undivided. Chromosomes displaced somewhat to right and left in order to show each one more clearly.

FIG. 38.—Anaphase of the first spermatocyte mitosis. Oblique polar view. Eleven dyads at upper pole and eleven plus the accessory (No. 5) at the lower pole. The end of the accessory towards the plate has split widely while the proximal end is still intact.

FIG. 39.—*Idem.* Same view. Eleven dyads at lower pole and eleven plus the accessory at the upper.

FIG. 40.—Second spermatocyte metaphase. Eleven dyads present, plus the accessory, which is about the size of the No. 10's as in the spermatogonia. Because of its failure to divide in the last mitosis, the accessory is just twice as large in comparison with the other chromosomes.

FIG. 41.—Second spermatocyte metaphase. Eleven dyads present, but no accessory. The unnumbered element near the center of the complex does not belong in the cell. It is a spot of ink that accidentally got on the drawing and was overlooked in the correction of the proof. In this and the preceding cell the relative sizes of the chromosomes are very apparent. Nos. 12, 11 and 10 may easily be recognized by their large size, and 1, 2 and 3 by their small size.

FIG. 42.—Second spermatocyte anaphase, eleven chromosomes.

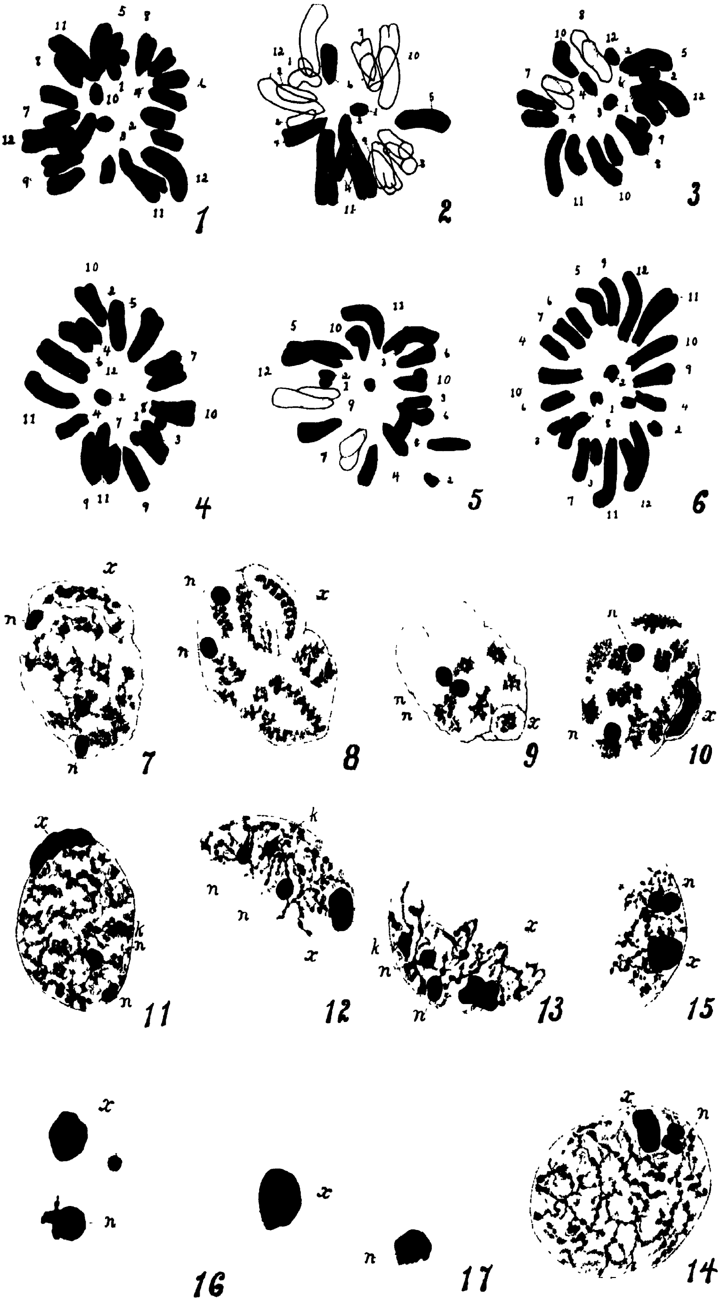
FIG. 43.—*Idem.*

FIG. 44.—Second spermatocyte anaphase, twelve chromosomes.

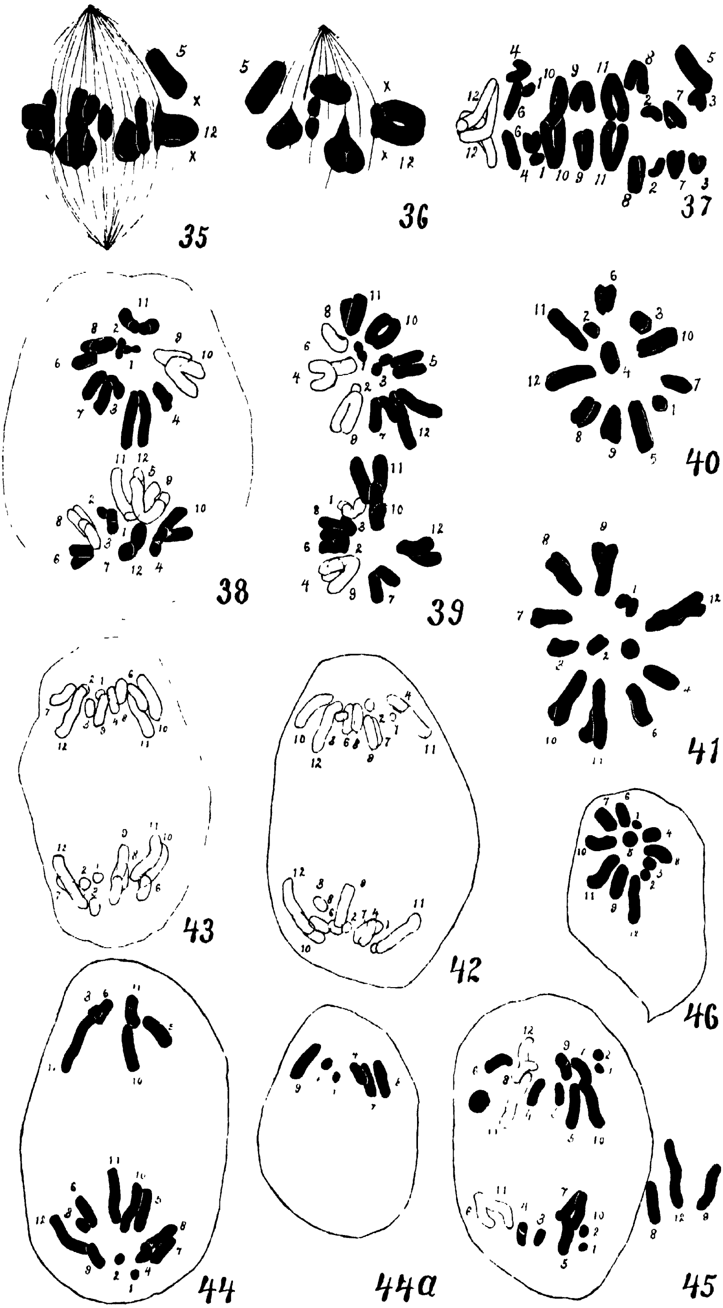
FIG. 44*a*.—Fragment of figure 44 found in next section.

FIG. 45.—Another second spermatocyte anaphase, twelve chromosomes. The large round element in the left part of the figure is not present in the cell but is the result of the same accident as that in figure 41. It is to be disregarded.

FIG. 46.—A spermatid of the twelve-chromosome type. Accessory viewed from end.



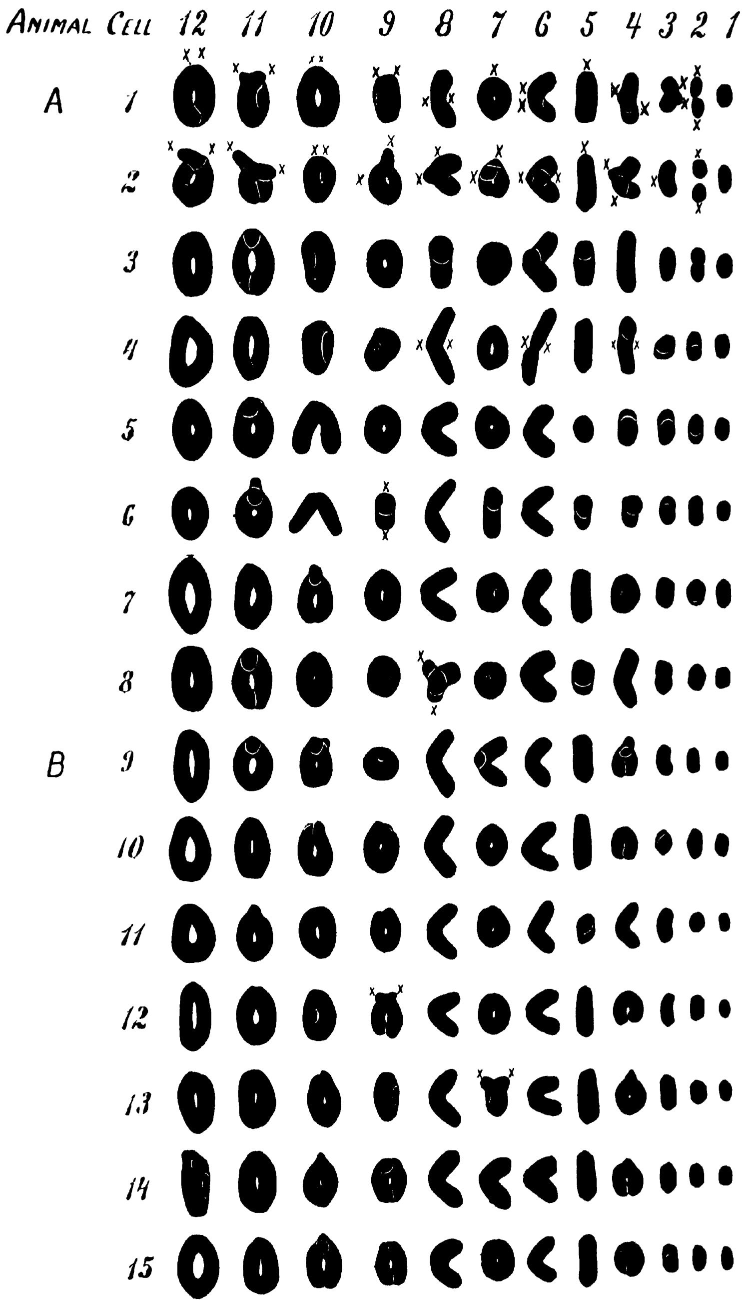

18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

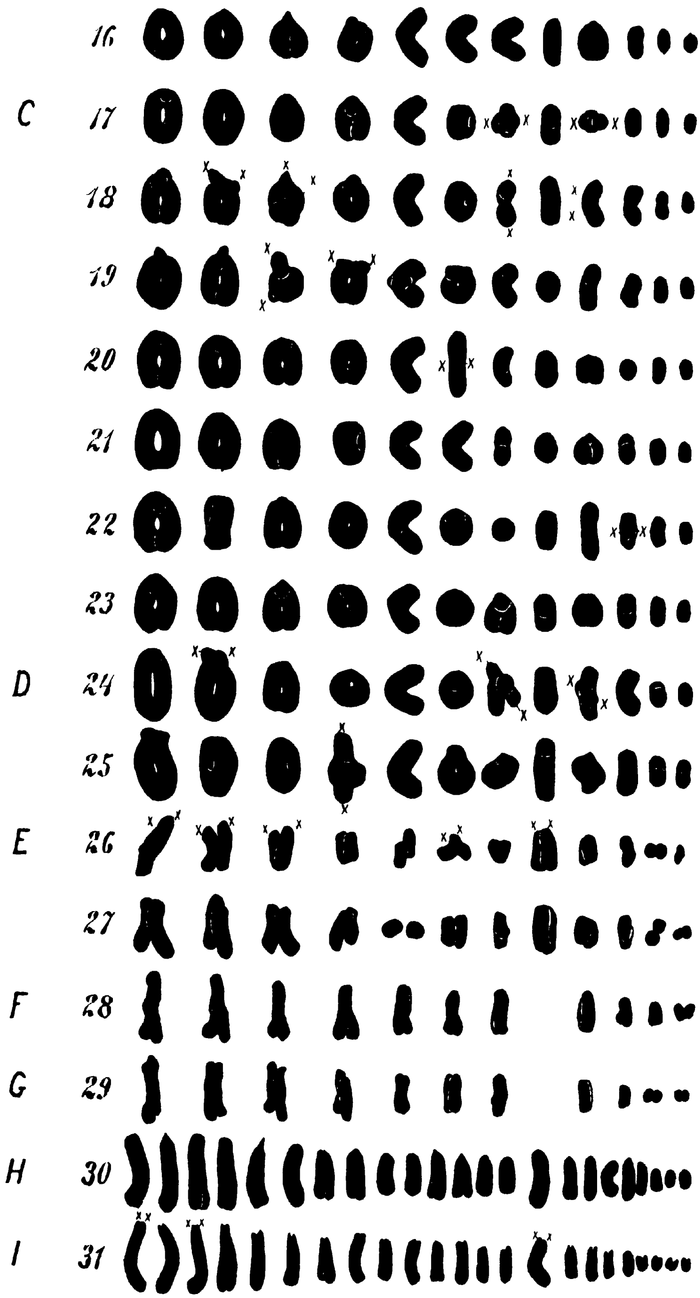

35
36
37
38
39
40
41
42
43
44
44a
45
46

EXPLANATION OF PLATES XXI, XXII.

The twelve chromosomes of each cell are arranged in a series or row horizontally. The series are placed one below the other, so that like chromosomes always appear in the same column. The number (at top of page) of the column in which a chromosome occurs is the number by which the particular individual chromosome which that column contains is known. The series or cell complex to which a chromosome may belong is indicated by the numbers at the left side of the plate. The capital letters at the left side of the plate designate the animal from which the series was taken. The characters *XX* indicate the proximal part of the chromosome, the point at which the spermatogonial pair conjugated. They also indicate the points of attachment of the spindle fibers, and in those chromosomes that are part way advanced into mitosis the ends of the transverse axis. In the second spermatocytes and the spermatogonia they indicate, as above, the attachment of the fibers and the proximal or polar end of the chromosome.

The first twenty-five series are taken from first spermatocyte metaphases, such as are seen in figures 30-33. Series 26-29 were taken from second spermatocyte metaphases, such as figures 40 and 41 (Series 28 is from fig. 41, plate XX); and series 30 and 31 were taken from the spermatogonial metaphases shown in figures 2 and 6 of plate XVIII. All of the series except 24 and 25 are from cells that were stained with iron-hæmatoxylin. Series 24 and 25 were stained with Flemming's tricolor, which has a tendency to swell the structures. The magnifications are the same as in the preceding plates and the drawings were made in the same way.


ANIMAL CELL 12 11 10 9 8 7 6 5 4 3 2 1
A
B
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


16
C 17
18
19
20
21
22
23
D 24
25
E 26
27
F 28
G 29
H 30
I 31

EXPLANATION OF PLATE XXIII.

Drawings made from sections of the testis of Phrynotettix magnus.

FIG. 1.—Metaphase of a spermatogonial cell showing all of the chromosomes. (x) Accessory chromosome.

FIG. 2.—Typical spermatogonial cell in anaphase. (x) Accessory chromosome.

FIG. 3.—Telophase of the same showing the persisting spindle fibers.

FIG. 4.—Later telophase. Note the encroaching division-wall contracting the spindle. The section is cut parallel with the long axis of the chromosomal vesicles. (x) Accessory chromosome in longitudinal section. (a) Polar granule.

FIG. 5.—Cross-section of the chromosome group of a cell in the same stage as those shown in figure 4. The polar granule of the accessory is shown.

FIG. 6.—A telophase slightly later than that shown in figures 4 and 5. Polar granules located at the proximal ends of the chromosomes.

FIG. 7.—Cross-section through the proximal end of a group of chromosomes showing a number of polar granules.

FIG. 8.—A cross-section through the distal portion of a similar group. No chromatin bodies of definite form appear in this plane.

FIG. 9.—A typical spermatogonial cell showing the diffusion of chromatin at its maximum within the vesicles. This stage marks the end of the telophase.

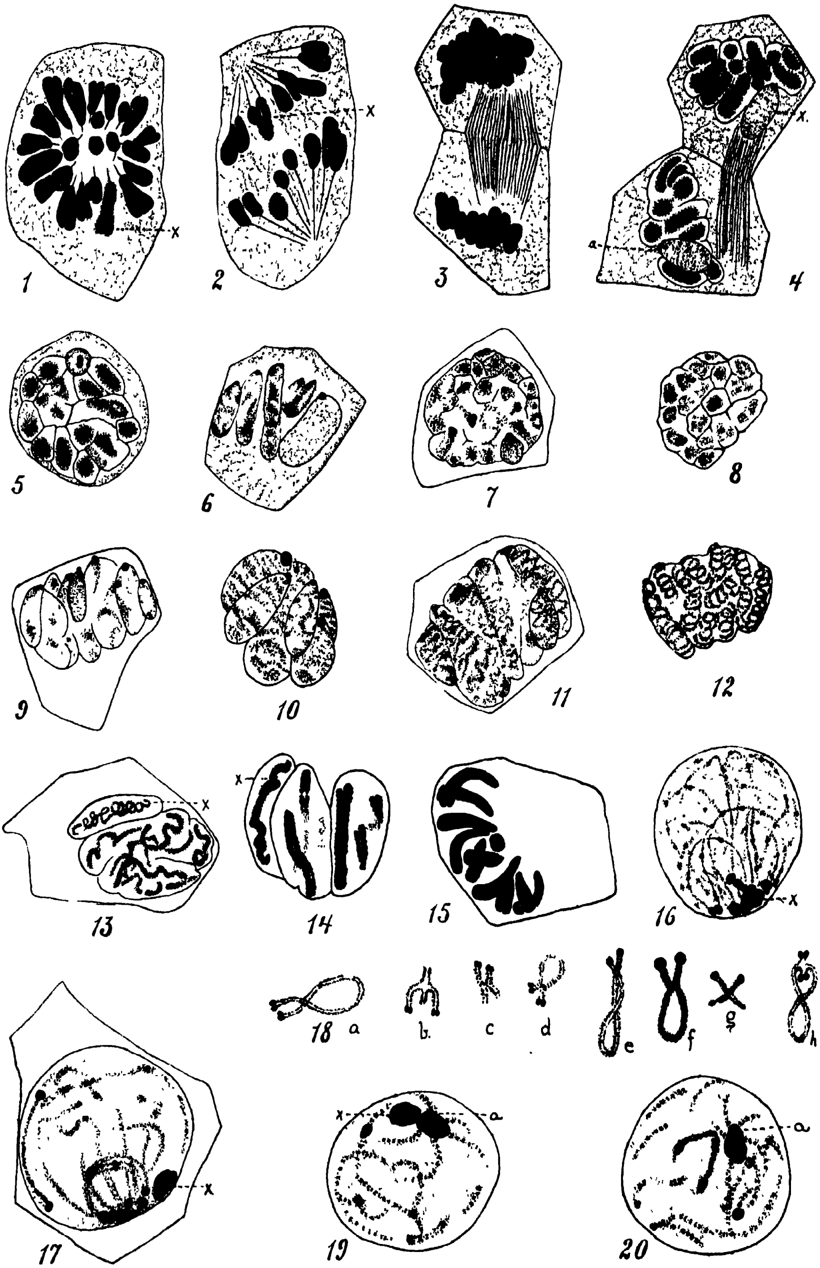
FIGS. 10, 11, 12, 13, 14, 15.—Cells showing the succession of typical changes occurring in the spermatogonial prophases. (x) Accessory chromosome.

FIG. 16.—Early spermatocyte prophase. (x) Accessory chromosome showing its characteristic position. The lesser bodies are the polar granules. Note the looped arrangement of the chromatin thread.

FIG. 17.—A slightly later spermatocyte prophase. The chromatin thread is contracting. (x) Accessory chromosome.

FIG. 18.—Spermatocyte tetrads. The bulbous thickening or polar granules mark the point of spindle fiber attachment. a, e, h, show the tetrads which later form the large rings shown in figures 22 and 23. (f) is a similar tetrad in a more condensed state. In (h) the separation resulting in bivalent chromosomes has begun. In (b) the separation has apparently progressed still further.

FIGS. 19, 20.—The same stage as shown in figure 17. (x) Accessory chromosome with no chromatin threads attached. (a) A deeply staining mass of homogeneous chromatin with radiating chromatin threads showing a longitudinal division. The chromomeres are in evidence.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
a
b.
c
d
e
f
g
h
19
20
x
a

EXPLANATION OF PLATE XXIV.

FIG. 21.—Late prophase of first spermatocyte showing the quadrivalent character of the chromosomes.

FIGS. 22, 23.—First spermatocyte metaphases. Note the constancy in form and number of the chromosomes.

FIGS. 24, 25.—Succeeding metaphases following the stage shown in figure 23.

FIGS. 26, 27.—Anaphases of first spermatocyte.

FIG. 28.—Telophase of the first spermatocyte. The homogeneous condition of the accessory chromosome is characteristic. The bivalent character of the chromosomes is apparent.

FIG. 29.—Later telophase of the same. The polar granules are seen in the polar ends of the dyads.

FIG. 30.—Metaphase of the second spermatocyte showing twelve dyads.

FIG. 31.—Same stage. A lateral view of the mitotic figure.

FIG. 32.—Anaphase of the second spermatocyte resulting in the separation of chromatids.

FIG. 33.—An early stage in the developing spermatid. (*a*) The spindle fiber remains. Note also the small round bodies staining like homogeneous chromatin within the nucleus.

FIG. 34.—A later stage in the developing spermatid. (*a*) Middle-piece staining like the chromatin bodies in the nucleus of figure 33.

PLATE 24

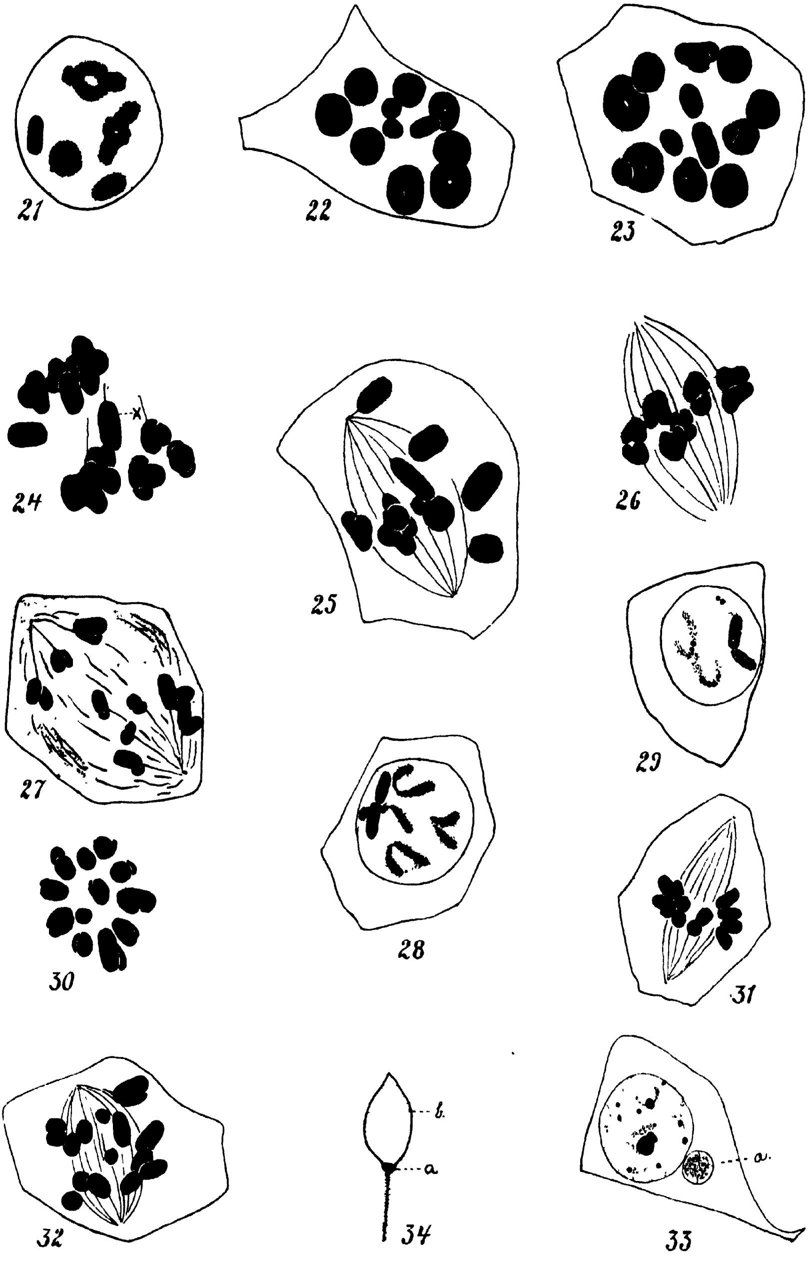
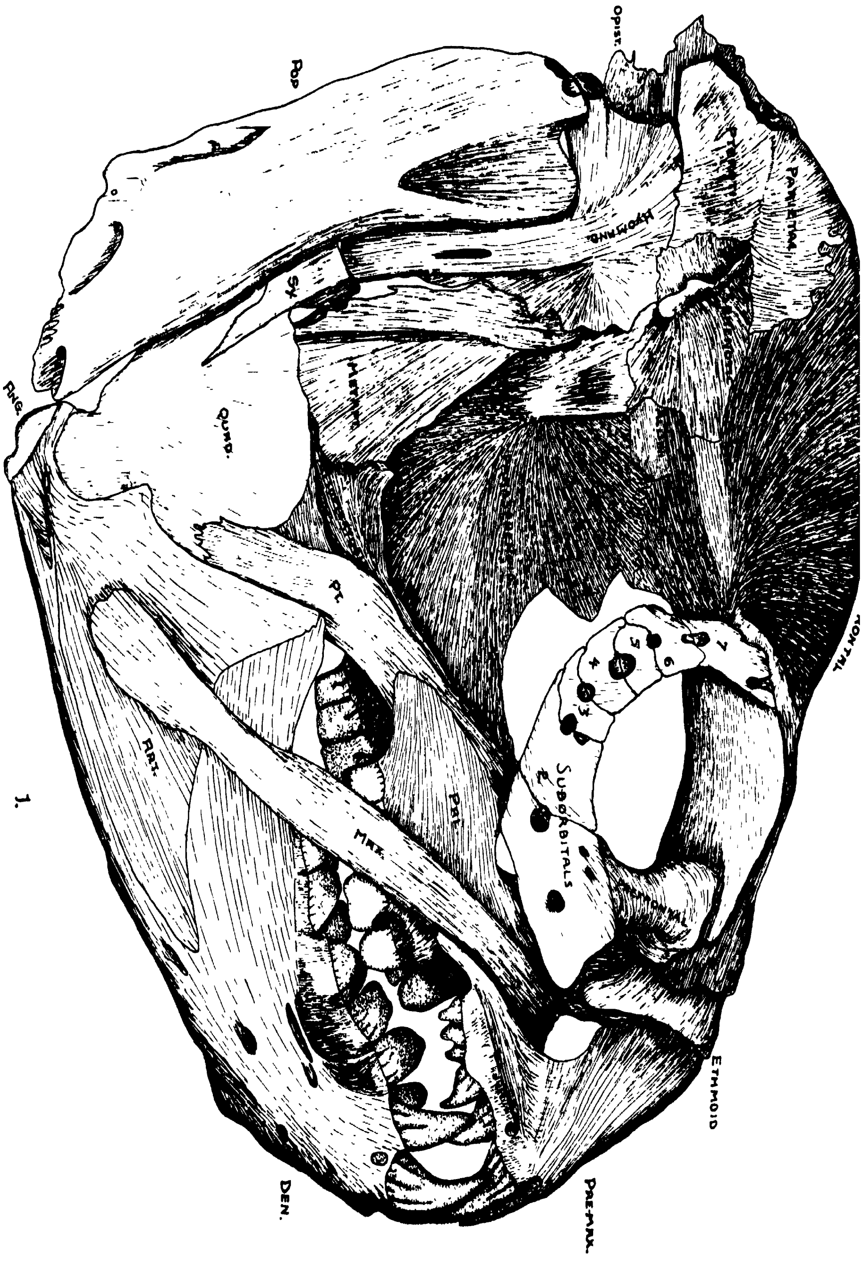


PLATE XXV.

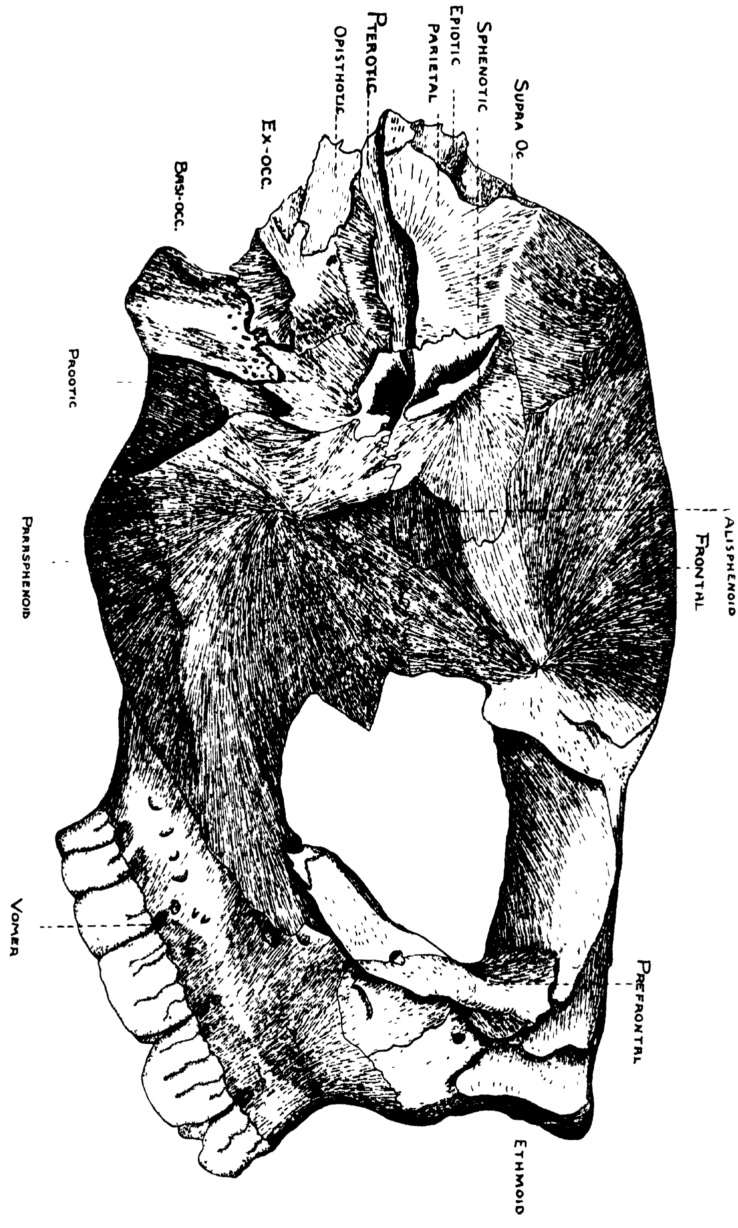
Right lateral view of the skull of the wolf-eel, ***Anarrhichthys ocellatus***, with suspensorium and mandible *in situ*. Natural size.


Pop
Opist.
Parietal
Hyomand
Sy
Met
Ang.
Quad.
Pt.
Art.
Pal.
Max.
Suborbitals
1
2
3
4
5
6
7
Frontal
Ethmoid
Den.
Pre-max.

1.

PLATE XXVI.

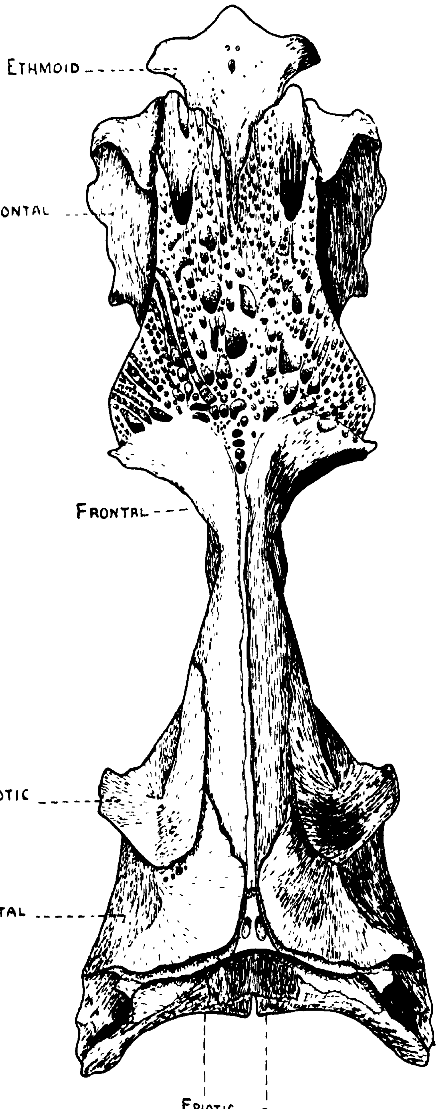
Right lateral view of the skull of *Anarrhichthys ocellatus*, stripped of the suspensorium and the mandible. Natural size.


SUPRA OC.
SPHENOTIC
EPIOTIC
PARIETAL
PTEROTIC
OPISTHOTIC
EX-OCC.
BASI-OCC.
PROOTIC
PARASPHENOID
VOMER
ALISPHENOID
FRONTAL
PREFRONTAL
ETHMOID

2.

PLATE XXVII.

Dorsal view of the skull, stripped. Natural size.


Ethmoid
Prefrontal
Frontal
Sphenotic
Parietal
Epiotic
Supra oc

3

PLATE XXVIII.

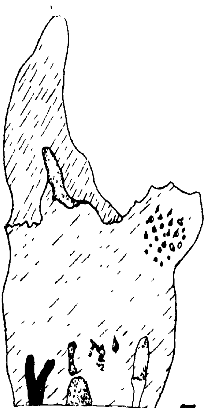
FIG. 4.—Posterior view of the stripped skull. Natural size.

FIG. 5.—Outer view of the premaxilla. Natural size.

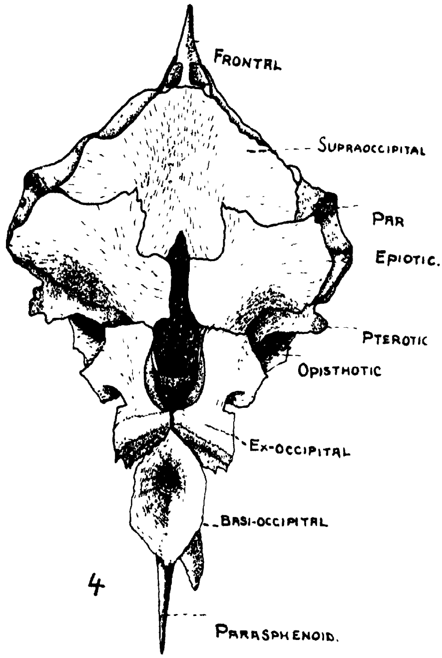
FIG. 6.—Premaxilla, inner view.

FIG. 7.—Longisection of tooth from premaxilla, X 2.

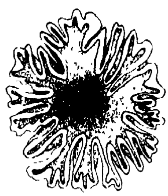
FIG. 8.—Basal view of canine, X 5.



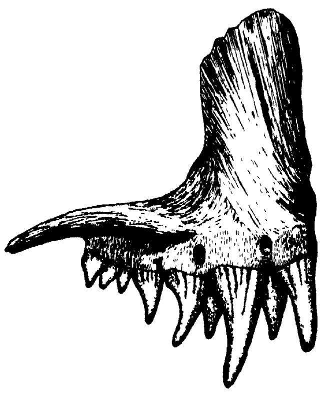
×4 7


FRONTAL
SUPRAOCCIPITAL
PAR
EPIOTIC.
PTEROTIC
OPISTHOTIC
EX-OCCIPITAL
BASI-OCCIPITAL
PARASPHENOID.

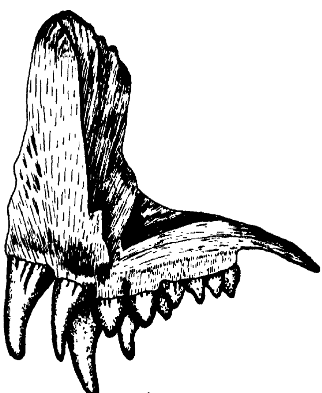
4



×10 8



5.



6.

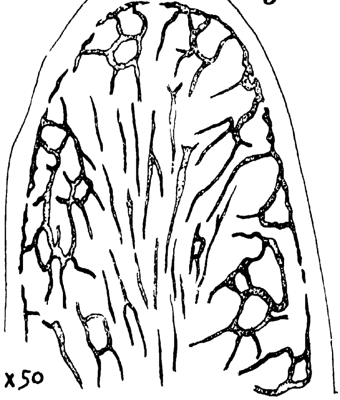
PLATE XXIX.

FIG. 9.—Longisection of a canine, X 25.

FIG. 10.—Transverse section of a canine, X 48.

FIG. 11.—Skull with the right half cut away.

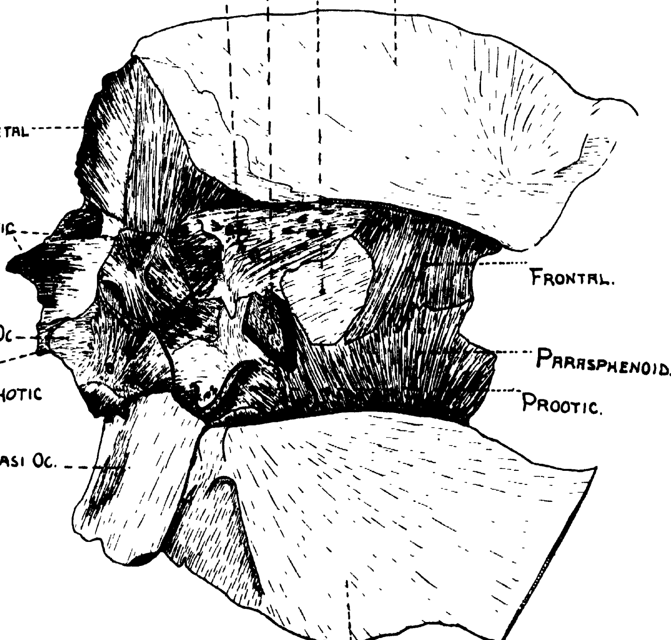
9



x50

X 96

10



11.

PLATE XXX.

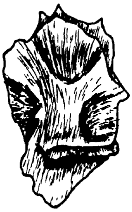
Figs. 12, 13, 14.—Right prootic, inner, anterior and exterior views.

Fig. 15.—Right opisthotic.

Figs. 16, 17, 18, 19.—Right supraoccipital, posterior, lateral, dorsal and ventral views.

Figs. 20, 21, 22, 23.—Basioccipital, posterior, anterior, lateral and ventral views.

Fig. 24.—Vomer, ventral view. Natural size.

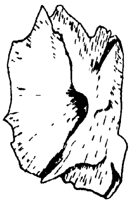


INTERIOR

12

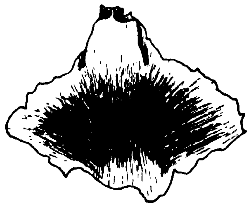
ANTERIOR.

13



EXTERIOR

14



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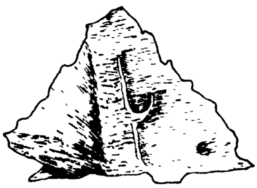
15.



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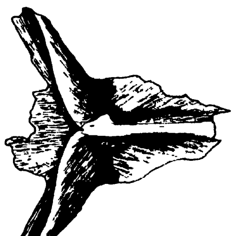

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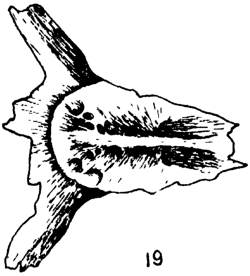

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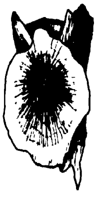

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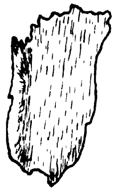

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PLATE XXXI.

FIGS. 25, 26.—Mesopterygoid, outer and inner views.

FIGS. 27, 28.—Metapterygoid, outer and inner views.

FIGS. 29, 30, 31.—Epiotic—inner, dorsal and posterior views.

FIGS. 32, 33, 34.—Exoccipital—outer, posterior and inner views.

FIG. 35.—Frontal, lateral view. Natural size.


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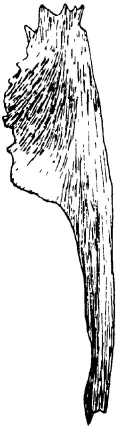
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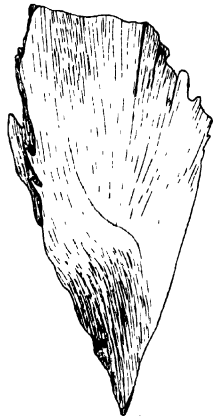
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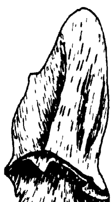
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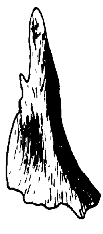
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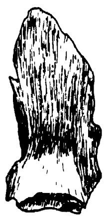
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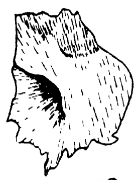
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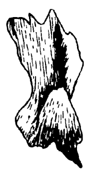
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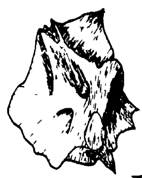
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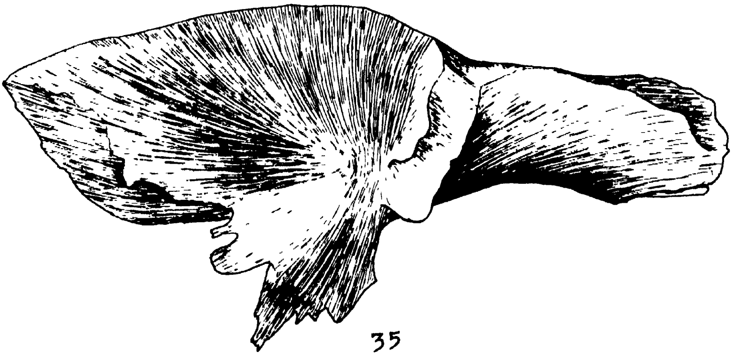
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PLATE XXXII.

FIG. 36.—Frontal, ventral view.

FIGS. 37, 38, 39.—Prefrontal—lateral, dorsal and inner views.

FIGS. 40, 41.—Parasphenoid—lateral and dorsal views. Natural size.

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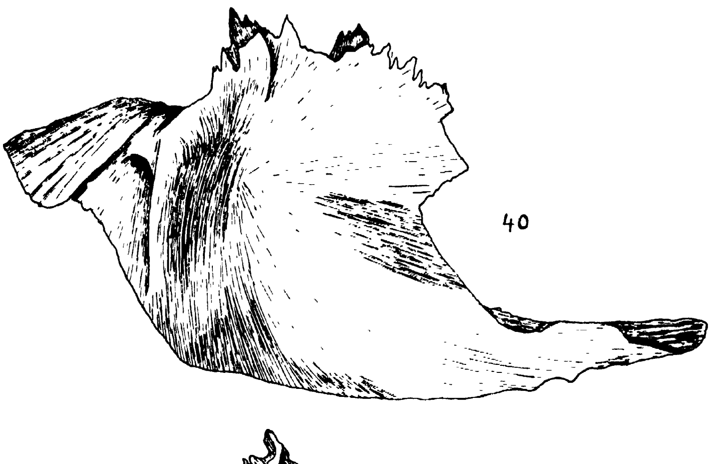

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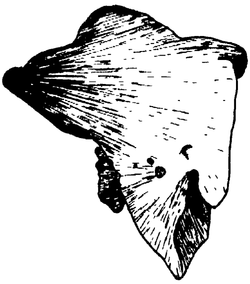
PLATE XXXIII.

FIGS. 42, 43, 44.—Ethmoid—lateral, dorsal and anterior views.

FIG. 45.—Alisphenoid, outer face.

FIGS. 46, 47, 48.—Sphenotic—outer, posterior and inner views.

FIGS. 49, 50, 51, 52.—Parietal and pterotic—lateral, inner, anterior and posterior views.



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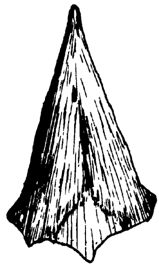

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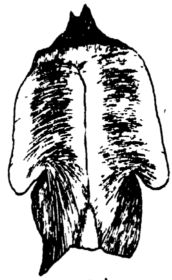

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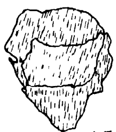

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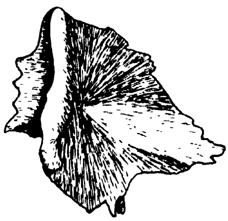

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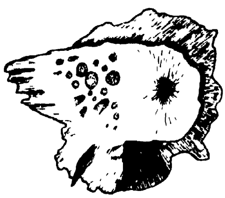

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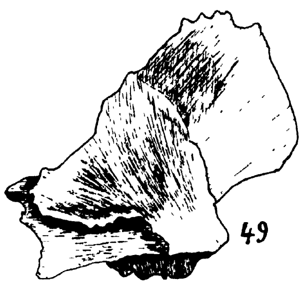

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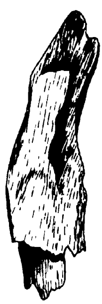

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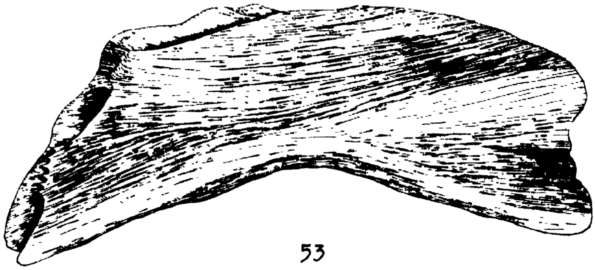
PLATE XXXIV.

FIGS. 53, 54.—Preopercular, outer and inner views.

FIGS. 55, 56.—Hyomandibular, inner and outer faces.



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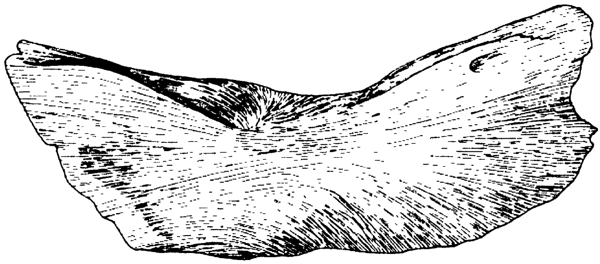

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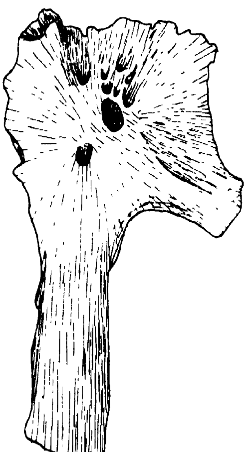

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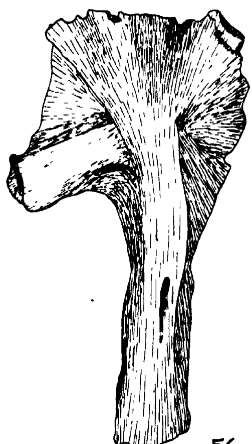

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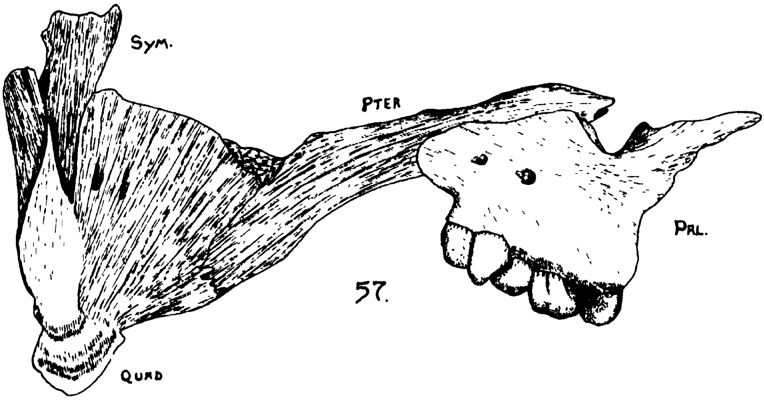
PLATE XXXV.

FIGS. 57, 58.—Quadrate, symplectic, pterygoid, palatine, outer and inner views.

FIGS. 59 (marked 58 on plate), 60.—Maxilla, inner and outer views.



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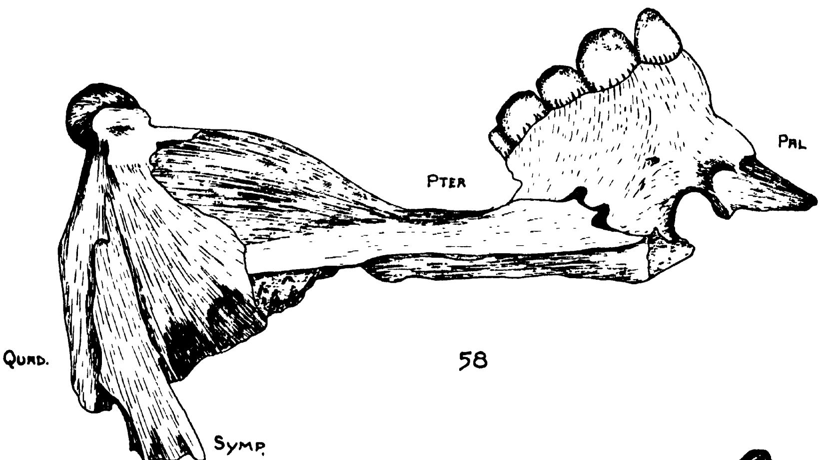

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PLATE XXXVI.

Fig. 61.—Mandible, outer view, showing dentary, angulare and articulare.

Fig. 62.—Inner view of the mandible.

Fig. 63.—Mandible, dorsal view.

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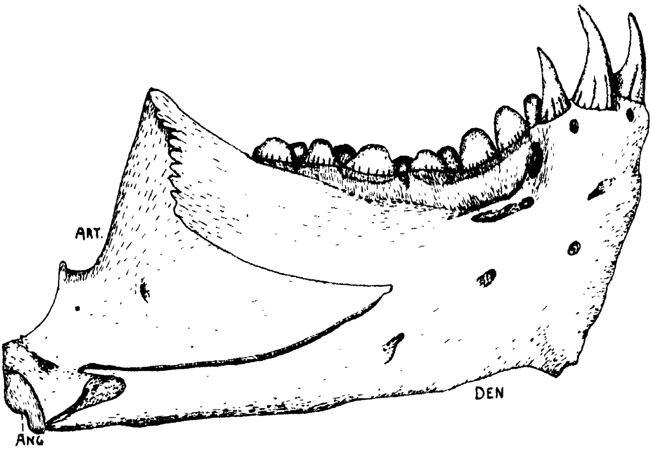

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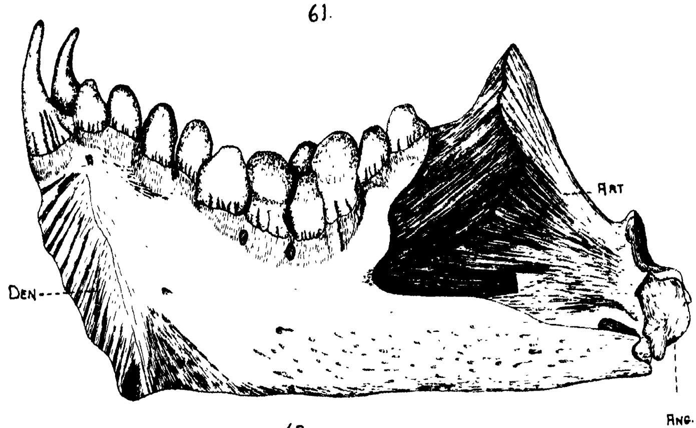

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EXPLANATION OF PLATE XXXVII.

FIG. 1.—Ventral view of grasshopper, showing heart-tube and some of the tracheal tubes in place in the chitin, but all other systems are removed. *a*, Air-sacs; *h*, heart-tube; *t*, tracheal tube; *m*, alary muscles, showing attachment; *s*, muscles connecting segments of abdomen.

FIG. 2.—Histological cross-section through heart. *a*, Alary muscles; *b*, fibrous layer; *c*, connective-tissue or pericardial cells; *d*, connective-tissue cells; *e*, ganglion-cells (?); *f*, muscle of heart; *h*, heart cavity; *t*, tracheal tubes; *i*, nerve-like cells. (Chrome-oxalic fixative, Nissl stain).

FIG. 3.—Longitudinal section of heart with corresponding structures labeled same as for figure 2. (Formalin fixative, iron-hæmatoxylin stain.)

FIG. 4.—So-called ganglion-cells. Same as *e*, figures 2 and 3. (Formalin fixative, iron-hæmatoxylin stain.)

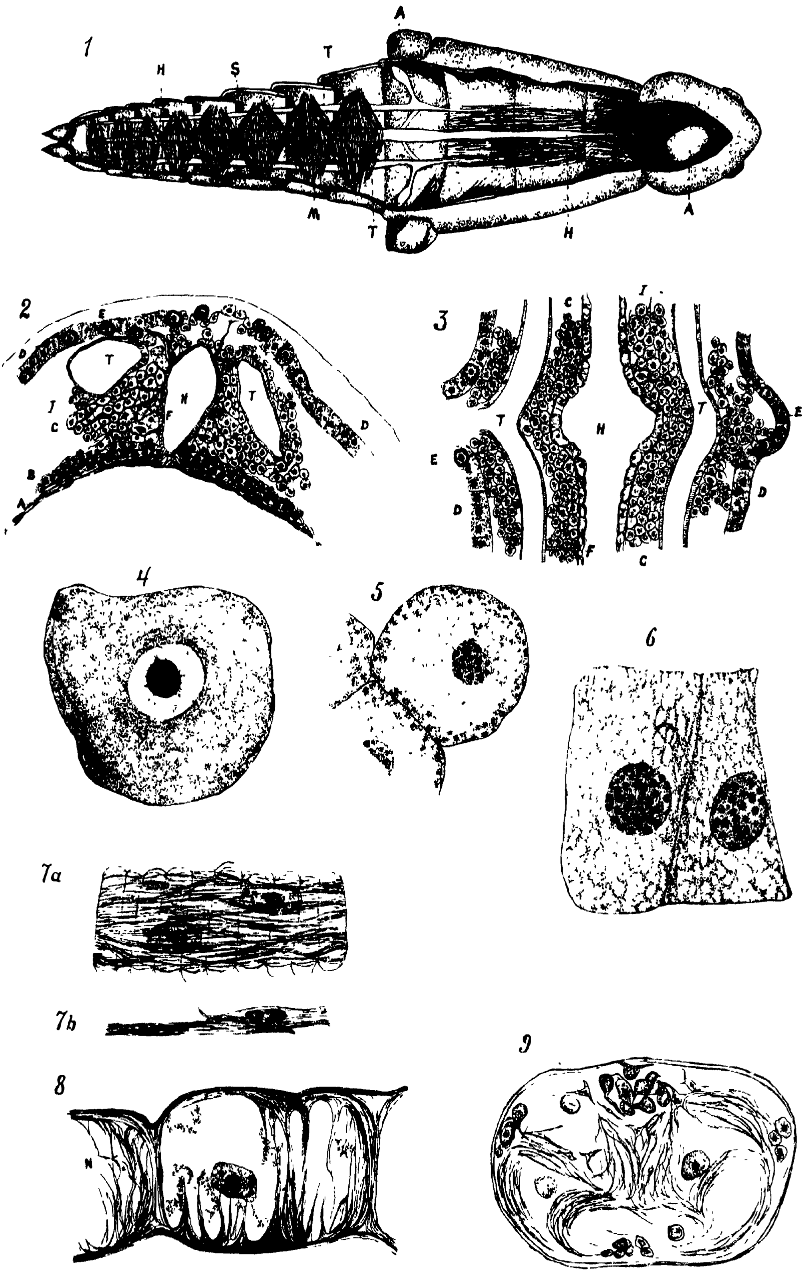
FIG. 5.—Pericardial cells, enlarged. Same as *c*, figures 2 and 3.

FIG. 6.—Connective-tissue cells enlarged. Same as *d*, figures 2 and 3. (Figures 5 and 6, chrome-oxalic fixative, Nissl stain.)

FIG. 7.—*a*, Cross-section of heart-muscle (*f*, of figure 2); *b*, single fiber from cross-section of heart. (Figure 7, *a* and *b*, formalin fixative, iron-hæmatoxylin stain.)

FIG. 8.—Longitudinal section through heart-muscle (*f*, figure 3), showing fibers and nerve-like cells (*n*). (Stain and fixative same as for figure 7.)

FIG. 9.—Section through a thoracic ganglion. (Van Gehuchten's fixative, Nissl stain, with erythrosin for a counter-stain.)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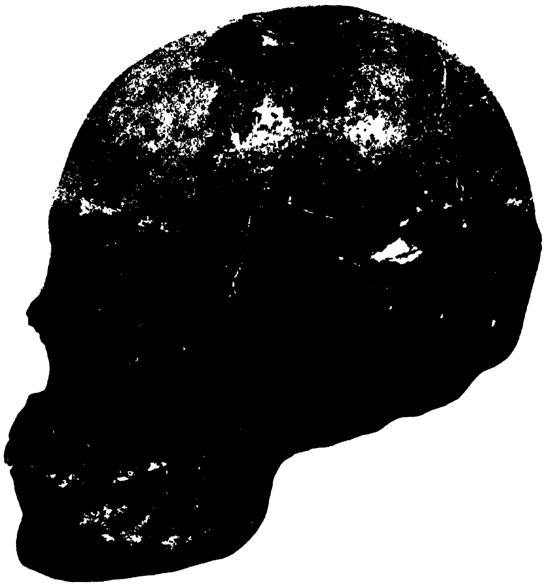
EXPLANATION OF PLATE XXXVIII.

FIG. 1. Skull found at San Blas. Lateral view. × ½.

FIG. 2. Camp of the University of Kansas expedition to Patagonia on Señor H. S. Felton's estancia, showing location where the Killik Aike skull, shown on plate 39, was found. Exact spot indicated by the small x.



EXPLANATION OF PLATE XXXIX.

FIG. 1. Lateral view of Killik Aike skull found on Señor H. S. Felton's estancia, Rio Gallegos, Patagonia, locality shown in text figure 1.

FIG. 2. Superior view of Killik Aike skull.

EXPLANATION OF PLATE XL.

FIGS. 1-10, inclusive, represent pottery found associated with skull shown on plate 38, fig. 1, from San Blas, Rio Negro Territory, Argentine Republic.

Lower left-hand figures show arrow points found with above skull.

Lower right-hand figures show boleadores found on the estancia of Señor H. S. Felton, Rio Gallegos, Patagonia.